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**HEDGING STRATEGIES AND PRICE RISK:
AN EMPIRICAL ANALYSIS**

by

Debra R. Hunter, B.S., M.B.A.

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Business Administration

COLLEGE OF ADMINISTRATION AND BUSINESS
LOUISIANA TECH UNIVERSITY

March 2004

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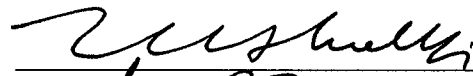
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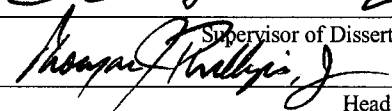
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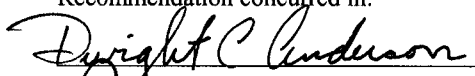
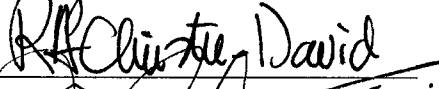
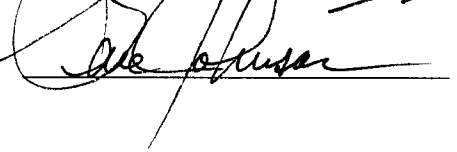
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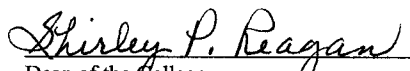




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ABSTRACT

This dissertation focused on the use of futures contracts as a hedge against price risk and is motivated by two key questions. First, will daily corn (soybean) futures prices consistently yield higher/lower prices than daily cash spot prices, after adjusting for an arbitrage bound? Second, does a hedge ratio exist that minimizes price risk for corn (soybean) producers?

Data consisted of daily futures prices and daily cash spot prices for corn (September/December) and soybean (November/January) contracts for the period 1970 through 2000. These two commodities have the largest futures trading and highest production volume of all agricultural commodities.

Two primary data analysis techniques were applied. First, price differences were analyzed using a timing model, adjusted for an arbitrage bound. The results from the timing model do not support the null hypothesis that “a time frame does not exist in which daily corn (soybean) futures prices are consistently higher/lower than the related daily cash spot price, after adjusting for an arbitrage bound.” In fact, the results suggest that futures prices more often fall “below” the arbitrage lower bound limit than they do within or above the bound.

Second, the data was analyzed using a mean-variance framework and a logarithmic utility function to determine hedge ratios for corn (soybeans). The calculated

hedge ratios do not support the null hypothesis that “a partial hedge will not consistently allow a producer to receive a higher average price than a full hedge of expected corn (soybeans) yield.” Specifically, the results for both corn contracts and the November soybean contract suggest that producers should hedge less than 100% of expected output while the results from the January soybean contract suggest that producers should hedge more than 100% of their expected output.

KEY WORDS: Arbitrage Bound, Commodity Futures Contracts, Corn, Hedge Ratios,
Soybeans

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Author Delon R. Hunter

Date February 28, 2004

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CHAPTER ONE

INTRODUCTION

Agriculture and the agribusinesses supporting it account for approximately 15% of the American workforce.¹ For the year 2000, total farm output equaled \$214.7 billion of the nation's annual production;² additionally, agricultural items accounted for \$53.7 billion (or 8%) of the nation's overall exports.³ Therefore, a downturn in the agricultural sector would have grave consequences on the overall U.S. economy as well as the individual commodity producer.

Given the significance of the agricultural sector of the economy, U.S. policy has traditionally supported agriculture through crop subsidies. Results from prior research suggest that land values incorporate traditional subsidies (see Chapter 2, Subsection 2.1) and a reduction in such subsidies would affect the landowner (whether a producer or not) but would not directly affect a non-landowning producer. It is interesting to note that Congress eliminated or substantially reduced traditional subsidies for most crop

¹Based on the 1997 U.S. Agricultural Census (taken every 5 years) conducted by the Economic Research Service for the United States Department of Agriculture (USDA). The 2002 Census results will be published beginning in February, 2004.

²Taken from the 2002 Statistical Abstract of the U. S. published by the U.S. Census Bureau, Table No. 791.

³Taken from the 2002 Statistical Abstract of the U.S. published by the U.S. Census Bureau, Table No. 804.

commodities through passage of the Federal Agriculture Improvement and Reform Act (FAIR) in 1996. As discussed in Chapter Two (Section 1, Subsection 1.1), subsidies since 1996 have provided producers, but not landowners, price and/or output relief.

In the late 1990's, market prices of corn and soybeans fell from their 1997 historical highs to prices not seen since the 1970's. This price decline resulted primarily from high world output. As a consequence, Congress subsidized producers through loan deficiency payments (LDPs or “pop” payments)⁴ in 1998, 1999, 2000, and 2001. The value of these payments peaked in 2000 at \$6.48 billion and declined in 2001 to \$5.70 billion. Congress also provided disaster relief to southern producers for low yields (based on historical average yields)⁵ caused by drought and aflatoxin, a corn disease, in 1998. Historically, the government also provided producers with production flexibility payments; the amount paid under this program has steadily declined from 1997 (\$6.12 billion) to 2001 (\$4.04 billion). While subsidies provide producers price and/or output relief, producers have no guarantee that such legislation will continue in the future. Lence and Hayes (2002) state that it will take decades for the market to reach a new equilibrium and we will not know the ultimate impact of the FAIR Act until that equilibrium occurs. Therefore, crop producers must seek alternative financial measures to achieve income stability.

⁴These payments are calculated as the difference between the world price on the date the commodity is delivered to the grain elevator less a grain specific location differential (i.e., the further the elevator is from a designated port location, the higher the differential) versus the specified governmental loan rate.

⁵Historical averages available by field from information filed by producers with the Farm Service Agency (FSA), an agency of the U.S. Department of Agriculture (USDA).

One alternative is greater participation in federal crop insurance programs. Several authors have researched the effect of crop insurance. Innes (2003) looks at the economic costs of using crop insurance while Young, et al. (2001) focus on the effects crop insurance has on acreage planted by crop, prices, and producer net returns.

This dissertation focuses on another alternative. Specifically, this dissertation evaluates the use of futures contracts as a hedge against price risk and is motivated by two key questions. First, will the purchase of daily corn (soybean) futures contracts consistently yield higher prices than accepting daily cash spot prices, after adjusting for an arbitrage bound? Second, does a hedge ratio exist that minimizes price risk for corn (soybean) producers? Prior research has not specifically addressed either of these issues.

The remainder of this introduction is organized as follows. Section 1 contains a discussion of (commodity) market efficiency while Section 2 addresses hedging. Section 3 provides an overview of the hypotheses tested. Data collection techniques employed in this dissertation are presented in Section 4 while Section 5 includes a discussion of data analysis. Finally, Section 6 addresses the limitations of this research and Section 7 provides a summary of the organization of the remainder of this dissertation. For the reader's convenience, the chapter concludes with a list of definitions.

Section 1: Market Efficiency

Fama (1970), in a capital market context, defines a weak-form efficient market as one where prices reflect all historical price or return information. In turn, he defines a semi-strong form efficient market as one where prices reflect all historical price or return

information and all publicly available information. Finally, Fama defines a strong form efficient market as one incorporating all historical, public, and private information.

The extent to which markets are efficient has significant implications for prices of stocks in capital markets as well as commodities in futures markets. If these markets are not efficient, then traders with private knowledge could manipulate the markets on a daily basis to achieve excess returns; when the markets are efficient, traders cannot use information to manipulate the market and achieve excess returns on a consistent basis.

While private information in the capital market can be loosely defined as information known by a limited number of individuals employed by, or associated with, a particular company, it is more difficult to “define private information” in a commodity market for two reasons. First, numerous producers, both large and small, make individual decisions about acreage devoted to specific crops, type of seeds and fertilizer used, and the production methods employed. The USDA requires producers to report certain information, including acreage planted (by crop), at specific times throughout the year so the government can publish revised acreage estimates; the reports also include average annual yields by geographic location. Since the government publishes acreage by crop, the primary private information that exists relates to production methods and land quality; weather during the growing season provides another unknown to both producers and traders. Collecting production and land quality information from individual producers would be both costly and time consuming. This does not mean that certain individuals or firms cannot collect or purchase enough information to manipulate a given market (i.e., the Hunt’s manipulation of the silver market); it simply means that it is much more

difficult and costly to obtain private production information in the commodity markets than it is in the stock markets.

Second, because of the variety of potential uses for commodities (e.g., buyers may use corn as livestock feed or they may process it to make starch or food products, etc.), it would be costly and time consuming to obtain inside information from individual users about expected demand for a specific commodity. Thus, most research relating to commodity markets focuses on either the weak or semi-strong form of market efficiency.

For commodities, weak form efficiency means futures prices should reflect all historical price and return information and that trading strategies based on historical information will not consistently provide excess returns to investors. Semi-strong efficiency means futures prices should reflect all publicly available information such as beginning stores, acres planted, expected yields based on current/predicted weather patterns (e.g., expected drought, flooding, etc.), and expected consumption (i.e., demand). If, after accounting for transaction costs and interest rates consistent with Kolb's (1999) "arbitrage bound," commodity futures consistently provide higher/lower prices than daily cash spot prices, then traders may be systematically over or under pricing the commodity prior to actual harvest. Systematically over or under pricing may result from poor forecasting models relating to projected yields or expected usage. Given Fama's (1970) capital market definitions, if traders systematically over or under price corn or soybean futures in the commodity markets, it would call into question the efficiency of those markets. Accordingly, this dissertation evaluates whether the daily futures price would consistently yield a higher/lower price than the daily cash spot price.

Section 2: Hedging

Given the unpredictability of total output due to weather, pests, etc., the question arises whether a producer should purchase futures contracts for the total expected yield or for some percentage of the expected yield. Even though a producer could receive higher prices by purchasing futures contracts for total expected yield, the risk of producing less than the average annual yield may mean the producer would require a risk premium greater than the difference between the futures price and the expected cash spot price at harvest. The demand for a higher risk premium points out the need to evaluate whether a hedge ratio exists that minimizes price risk for corn (soybean) producers? Note that producers are assumed to be risk averse throughout the remainder of this dissertation.

Section 3: Hypotheses and Calculations

As previously indicated, this dissertation includes an evaluation of the premise that futures contracts would consistently yield higher/lower prices than the acceptance of daily cash spot prices, after adjusting for an arbitrage bound. Also, as stated above, this dissertation addresses whether a hedge ratio exists that minimizes price risk for corn (soybean) producers?

The following research question for corn (soybeans) is considered with respect to whether futures contracts provide prices that are consistently higher/lower than daily cash spot prices, after adjusting for an arbitrage bound.

Research Question 1:

When using Cumby and Modest's (1987) Timing Model, adjusted by Kolb's (1999) arbitrage bound, does a time frame exist to purchase corn (soybean) futures contracts that consistently provides a higher/lower futures price than the daily cash spot price?

The following provides a restatement of this question in the form of a null hypothesis.

Hypothesis 1 (null):

A time frame does not exist in which daily corn (soybean) futures prices are consistently higher/lower than the related daily cash spot prices, after adjusting for an arbitrage bound.

Hypothesis 1 is subdivided into two geographic regions (south and midwest) and tested individually for each geographic region. Because southern producers are able to plant earlier (i.e., the southern growing season begins earlier and is typically hotter than the midwestern growing season), futures contracts for corn (soybeans) expiring in September (November) relate to southern producers while contracts expiring in December (January) relate to midwestern producers. Additionally, this hypothesis will also be subdivided by groups of years where March inventory levels and March projected yields fall into specified ranges (low, medium, and high) to determine the predictability of bound violations based on these items. March inventory⁶ levels are used in the predictability test because March is the last quarterly inventory level available before both southern and midwestern producers must make their annual production decisions (i.e., decisions about which crops to plant and how many acres of each type of crop).

⁶ The USDA publishes grain stock levels on March 1, June 1, September 1 and December 1.

The following research question is considered with respect to what percentage of expected annual corn (soybeans) yield a producer should hedge.

Research Question 2:

When using Rolfo's (1980) mean-variance and logarithmic utility functions, does a hedge percentage exist for corn (soybeans) that consistently allows a producer to receive a higher average price than he would receive by purchasing futures contracts for 100% of his expected corn (soybeans) yield?

The following provides a restatement of this question in the form of a null hypothesis.

Hypothesis 2 (null):

A partial hedge will not consistently allow a producer to receive a higher average price than a full hedge of expected corn (soybeans) yield.

Similar to Hypothesis 1, Hypothesis 2 is subdivided into two geographic regions (south and midwest) and tested individually for each geographic region. If an optimal time frame for a producer to purchase futures contracts exists, it is expected to be approximately five to eight months before the futures contract would mature; this time frame is relevant because it represents the time frame during which producers make and implement decisions regarding acreage allotment between crops (i.e., crops that they plan to plant). Also, due to yield uncertainty resulting from weather variability (including the weather's impact on planting time), irrigation ability (including current year local restrictions on water usage), seed quality, pest problems, etc., the hedge ratio that will minimize producer price risk is expected to be less than 100% of the expected yield. For

the purposes of this dissertation, expected yield refers to the current number of acres planted multiplied by the (historical) average yield per acre.

Section 4: Data Collection

Data collection consists of obtaining prices for the specified futures contracts from the Futures Industry Institute (FII), interest rates for both a borrower and lender from the Federal Reserve, and inventory stock levels, acreage planted, and yield per acre information from the NASS⁷/USDA. The pertinent futures contracts for corn (soybeans) includes those contracts that require delivery in September (November) for the south and December (January) for the midwest. The data include daily contract prices for those futures contracts maturing at harvest and daily cash spot prices from 1970 through 2000 for both corn and soybeans. These two commodities have the largest futures trading volume and the highest production volume of all agricultural commodities; thus, soybeans and corn have liquid, active spot and futures prices. This characteristic makes corn and soybeans good choices for a study concerning the commodity futures markets.

Section 5: Data Analysis

With respect to Hypothesis 1, data analysis includes the use of Cumby and Modest's (1987) timing model, adjusted for Kolb's (1999) arbitrage bound. This process involves comparing daily futures prices for a particular contract to the daily cash spot price for a 31-year period from 1970-2000. With respect to Hypothesis 2, data analysis

⁷NASS stands for the National Agricultural Statistics Service.

includes the use of a mean-variance framework and a logarithmic utility function developed by Rolfo (1980) to determine the hedge ratios for corn (soybeans).

Section 6: Limitations of this Dissertation

All models and related tests in this dissertation address two commodities, corn and soybeans. There is no reason to believe that corn and soybean futures are not representative of other actively traded grain futures or of each other. The time horizon of the analysis includes the years 1970 - 2000. This time horizon was selected, in large part, due to data availability at the time of the initial analysis. The use of additional years of data may result in a different conclusion regarding the efficiency of the futures market and different hedge ratios for corn and soybeans.

Section 7: Dissertation Outline

The remainder of this dissertation is organized as follows. Chapter 2 provides a review of the literature while Chapter 3 presents the methodology. Chapter 4 includes an overview of the data collection process, the descriptive data and the results. Finally, Chapter 5 includes a summary of the test results, the limitations of this dissertation and future research opportunities. A more detailed outline follows.

Chapter 2: Literature Review

- Section 1:** U.S. Agricultural Policy and its Effects on Commodity Prices and Production
- Section 2:** Efficiency of the Commodity Futures Markets
- Section 3:** Hedging Strategies

Section 4: Conclusions (based on the significant elements of the previous three sections and the relationship of each element to the overall motivation for this dissertation)

Chapter 3: Methodology

Section 1: Hypothesis Related to the Value of Cash Spot Prices vs. Futures Contract Prices

Section 2 Hypothesis Related to the Hedge Ratio Percentage

Section 3: Models Used to Evaluate Hypotheses

Section 4: Conclusions

Chapter 4: Data and Empirical Findings

Section 1: Data Collection

Section 2: Arbitrage Band Model Results

Section 3: Hedge Ratio Model Results

Section 4: Conclusions

Chapter 5: Conclusions

Section 1: Summary and Implications

Section 2: Limitations and Suggestions for Future Research

The remainder of this chapter summarizes abbreviations used throughout this dissertation. It also includes definitions of key concepts.

Section 8: Definitions and Abbreviations

1. Backwardation - when the expected spot price exceeds the futures price; the excess of the expected spot price over the futures price represents a premium earned by the speculator that persuades them to bear the price risk.
2. Base acreage - the average number of acres planted, or considered planted, in a program crop during the preceding five years.
3. Basis - the difference between the current cash price and the futures price of the same commodity. Generally, the price of the nearby futures contract month is used to calculate the basis (Commodity Trading Manual 1994).
4. CBOT - Chicago Board of Trade.
5. Contango - when the futures price exceeds the expected spot price.
6. Convenience yield - benefit obtained from holding a physical commodity that holding a futures contract does not provide (Hilliard and Reis 1998).
7. CSCE - New York Coffee, Sugar, and Cocoa Exchange.
8. EMH (efficient market hypothesis) - theory stating that if a trader can earn a risk-adjusted profit,⁸ the market is not efficient and if the trader cannot, then the

⁸Marshall (1989) indicates the market should only provide speculators and other traders with enough profit to compensate them for systematic risk they bear. If traders earn profits in excess of the return provided for systematic risk based on forecasting efforts, the excess returns are “risk adjusted” profits.

market is efficient because asset prices have incorporated all currently available information (Dorfman 1993). Fama (1970) proposes three levels of efficiency: the weak form says asset prices incorporate all historical information; the semi-strong form says asset prices incorporate all historical information and current public information; and the strong form says asset prices incorporate all historical information and all current public and private information.

9. FAIR - the Federal Agriculture Improvement and Reform Act; also known as “The Freedom to Farm Act.”
10. Forward Contract - a cash contract where a seller agrees to deliver a specific commodity to a buyer at a specified future point. Unlike futures contracts, forward contracts are privately negotiated and are not standardized (Commodity Trading Manual 1994).
11. Futures Contract - a legally binding arrangement, developed on the trading floor of a futures exchange, to buy/sell a commodity or financial instrument at a stated point in the future. The only variable for futures contracts (standardized as to quality, quantity, and delivery time/location for each commodity) is price, which is discovered on an exchange trading floor (Commodity Trading Manual 1994).
12. Hedging
 - 1) (General) - the practice of taking an equal but opposite position in the futures market to offset the price risk inherent in any cash market position

to protect oneself or a business from adverse price changes which may occur between the current date and the date of the desired sale/purchase of the commodity (Commodity Trading Manual 1994).

- 2) (Producer Specific) - the practice of selling a commodity futures contract and/or forward contract to offset the price risk inherent in price changes which may occur between the current (perhaps the planting) date and the date of the desired sale (perhaps the harvest date).
13. Hedge Ratio - refers to the exact proportion of a crop which a producer should hedge; typically, this percentage is less than unity (one) because of yield variations due to weather, type of seed planted, etc.
14. ICAPM (Intertemporal Capital Asset Pricing Model) - CAPM refers to a model which uses a stock's beta (a measure of how a particular stock will move in relation to the market as a whole) along with a particular investor's risk aversion to calculate an investor's required return for a particular stock (Marshall 1989) and ICAPM refers to a multi-period model. Stated in terms of this dissertation, ICAPM refers to a multi-period model addressing futures contracts.
15. London Fox - London's Future and Options Exchange.
16. Long Hedge - the purchase of futures contracts to protect against a possible price increase of commodities that will be purchased in the future. When the commodities are bought, the hedger closes the open futures position by selling an

equal number and type of futures contracts as those that were initially purchased (Commodity Trading Manual 1994).

17. Maturity Effect - relates to futures prices exhibiting increased volatility as the contract maturity date nears because the futures price reacts more strongly to new information about the underlying commodity than the futures price related to contracts which have a longer term to expire (Milonas 1991).
18. Month Effect - relates to the crop cycle from planting to harvest and the related information available about the ultimate size and quantity of the harvest. Price volatilities are greater in months where changing weather conditions lead to significant price adjustments than in months where production yields are not seriously affected. This also relates to storage levels; stock levels decline as the year progresses which causes any news affecting supply or demand to have a greater impact on prices. To statistically detect a “month effect,” the year effect may have to be controlled (Milonas 1991).
 - 1) Calendar month effect (or seasonality) suggests price volatility increases in the summer months as the harvest approaches (Khoury and Yourougou 1993).
 - 2) Contract month effect reflects volatility due to a contract maturing in a month before the harvest of the new crop; i.e., a corn contract maturing before September (Khoury and Yourougou 1993).
19. NASS - National Agricultural Statistics Service

20. Reverse Hedging - for a producer this means the practice of buying (instead of selling) a position in the futures market.
21. Selling Hedge - the sale of futures contracts to protect against a possible decline in commodity prices for goods that will be sold in the future. When the commodities are sold, the hedger closes the open futures position by purchasing an equal number and type of futures contracts as those initially sold (Commodity Trading Manual 1994).
22. Settlement Price - refers to the price paid for the last contract traded on a given day. When a range of closing prices occurs (i.e., different prices on different contracts all closed at the end of the trading day), the CBOT averages the prices to determine the final settlement price (Commodity Trading Manual 1994).
23. Spot Price - generally refers to the cash market price for a physical commodity that can be delivered immediately (Commodity Trading Manual 1994).
24. SML - security market line.
25. Trading Session Effect - theory suggests that contract trading itself creates volatility.
26. U.S. - United States.
27. USDA - United States Department of Agriculture.

28. Year Effect - represents statistical evidence of higher price volatilities during entire crop years when events with worldwide effects on commodities occur. Examples include political events such as the U.S. embargo on grain exports to the Soviet Union during the Carter administration, economic events such as changes in the price level supports provided by the government, and major accidents such as the Chernobyl nuclear accident, etc. (Milonas 1991).

CHAPTER TWO

LITERATURE REVIEW

This chapter addresses the literature relevant to this dissertation; it is divided into four sections. Section 1 includes research regarding U.S. Agricultural Policy and the effect these policies have on commodity prices and production. Sections 2 and 3 provide a review of the literature addressing the efficiency of the commodity futures market and theories relating to hedging strategies, respectively. Finally, Section 4 includes a summary of the significant elements of the previous three sections and documents the basis for this dissertation.

Section 1: U.S. Agricultural Policy and Its Effects on Commodity Prices and Production

Section 1 contains two subsections. The first subsection presents literature relating to the government's use of subsidies to stabilize producer income. These studies do not address pre-production decisions; instead, they focus on the incorporation of subsidies into land values. The second subsection provides a review of the literature that analyzes the effect that government programs have on pre-production decisions relating to type of crops planted, number of acres planted in each crop, etc.

Subsection 1.1: Crop Subsidies

Several studies focus on whether a government subsidy affects the price of land or whether it affects the commodity price. Herriges, et al. (1992) study the value of corn base acreage; the authors believe that because base acreage provides the only access to price support programs, land values incorporate both the current and expected revenue from these programs. Herriges, et al. find that rental payments for “corn base acreage” land in Iowa are approximately \$11 to \$13 per acre per year higher than for comparable land which did not provide access to the support program. This accounts for approximately 11-14% of estimated land values.

To understand changes in (farm) land values, Just and Miranowski (1993) develop a structural model of land prices. Just and Miranowski indicate government support payments may account for roughly 15-25% of land values. Because Congress has passed legislation over the past 50 years to continue direct government payments for certain crops, both producers and landowners may reasonably expect this policy to continue. Therefore, Just and Miranowski suggest these subsidies do not explain large fluctuations in land prices.

In 1996, the United States Congress passed The Federal Agriculture Improvement and Reform Act (also known as “The Freedom to Farm Act” or “FAIR”). The Act substantially reduces direct commodity price support payments to U.S. commodity producers of program crops (i.e., corn, wheat, cotton, rice, sorghum, barley, and oats) beginning with 1998 and extending through 2002. By the end of 2002, the last year the current legislation addresses, Congress expects to pay approximately \$4.0 billion in crop

subsidies; under a 1990 farm bill, Congress budgeted \$7.8 billion for crop subsidies for the same time period (Lamb 1997).

Barnard, et al. (1997) measure the extent to which the provisions of FAIR could cause crop land values to fall. They find the effect of FAIR will vary across the country, primarily as a result of the dominant local crop. For example, their model forecasts that Corn Belt crop land values will decrease by an average of \$445 dollars per acre or 30% of the reduction in the direct government payment. Overall, for the eight regions for which Barnard, et al. report results, reductions in crop land values range from \$104 per acre (eastern Montana/North Dakota area) to \$903 per acre (Maryland/Eastern Pennsylvania area). These amounts represent a range of 12% to 69% of total land values. However, Barnard, et al. indicate that increased efficiency resulting from more flexibility in changing the type of crops planted from year to year, continued productivity gains, and strong export demand may offset some portion of this decrease in land value.

Smith and Glauber (1998) state that, on average, direct government payments account for less than 5% of total producer cash income during the five-year period from 1991-1995. They question the effectiveness of deficiency payments in providing revenue protection because the payment depends on the degree to which a producer's yield correlates with aggregate yield and price. For example, widespread droughts typically result in low yields which create high prices; this causes producers to receive small deficiency payments. Finally, Smith and Glauber state that most private and government analyses indicate that FAIR will create little to no change in either the acreage planted or the prices for wheat and food grains. They attribute any differences in these analyses to

differing assumptions about future market export growth and the implementation of the USDA Conservation Reserve Program over the next seven years.

In a discussion of federal crop insurance, Skees (1999) questions the economic reasoning behind any crop subsidy. He states, "Competition to get the 'good deal' reduces wages, raises asset values, and lowers the prices of outputs from the subsidized sector just enough to offset the benefits of the subsidies. Further competition restores wages, profits, and land rents to their presubsidy levels." Thus, subsidies merely reallocate factors from one part of the economy to another (i.e., from other areas to farming) and the landowner, not the producer, receives the benefit of any subsidies.

While most of the preceding research concludes that land values incorporate crop subsidies, this does not necessarily mean that subsidies will not affect non-owning producers. The incorporation of subsidies into land prices impacts non-land owning producers in at least three ways. First, the subsidy causes the producer to pay higher rent. Second, the producer receives the subsidy after complying with all required governmental regulations. Finally, the producer sells the commodity; the price support may affect the price available on the open market. Whether the subsidy benefits the producer depends on whether the subsidy generates more revenue for the producer than it costs in higher rent expense. When the government reduces subsidies, the non-owning producer may be helped or hurt depending on the net effect of changes in land rent expense, market prices, and loss of the subsidy.

Land owning producers receive two benefits; they receive the subsidy and the value of their land increases as a result of the subsidy. However, if the subsidy causes market prices to decline, then the subsidy may negatively affect the landowner's net

wealth. A reduction in subsidies affects the land-owning producer's overall wealth through a reduction in land prices, a potential change in commodity market prices, and a loss of the subsidy.

Based on the above, both land-owning and non-owning producers must find and implement mechanisms other than subsidies to stabilize income. While emergency assistance bills passed by Congress since FAIR appear to be aimed at subsidizing producers for low market prices, producers cannot depend on Congress to continue to provide this type of assistance. The futures market provides producers with an alternative method of stabilizing their income. This dissertation attempts to determine whether daily corn (soybean) futures prices consistently provide higher/lower prices than daily cash spot prices, after adjusting for an arbitrage bound (Section 2), and if there is a hedge ratio (Section 3) that minimizes price risk for the expected yield of corn (soybeans).

Subsection 1.2: Production Decisions

Some disagreement exists about the role the government should play in stabilizing farm prices and farm income. Additionally, disagreement exists about the effects that macroeconomic shocks have on commodity prices and commodity production decisions. A study by McKinnon (1967) indicates the government's myopic focus on spot prices and a corresponding disinterest in futures trading has led to inefficient and unsuccessful historic attempts to stabilize spot prices. He believes the government, and any other party interested in stabilizing prices, should confine its activities to stabilizing distant futures prices; public policy should encourage active futures trading, particularly by primary producers. McKinnon believes that confining the government's role to stabilizing futures

prices would negate the need for existing complex and inefficient commodity programs. Instead, the futures market would permit a more efficient allocation of commodity resources while simultaneously minimizing price risk for primary producers.

Romer (1991) provides a review of the cyclical nature of production for 38 different products, including 11 agricultural commodities (corn, wheat, oats, cotton, etc.), and seeks to identify the size, source, and correlation of production fluctuations for the period from 1889-1984. The review suggests that none of the agricultural commodities exhibit any stabilization in production volume over the 95-year period examined except for hay and Irish potatoes. Because of the minimal decline in volatility, Romer questions the idea that government intervention has radically reduced either the size of aggregate shocks to the economy in the postwar era or the response to such shocks. Factor analysis indicates that a common factor (common to mining, manufacturing, etc.) provides less explanatory power for agricultural commodities than for other types of goods. Romer believes this finding supports the theory that agricultural production is affected more by an industry specific, or even by a commodity specific, shock. Since World War II, agricultural production has changed from being mildly pro-cyclical to mildly counter-cyclical; it may be that a stronger dollar negatively affects commodity exports before affecting manufactured goods exports.

The Canadian Wheat Board, a Crown Agency, formulates policies that affect the wheat, barley, and oats markets in Canada. Khoury and Yourougou (1993) study the effect of five sources of agricultural futures markets volatility identified in the literature: the year effect, the calendar month effect, the contract month effect, the maturity effect,

and the trading session effect.⁹ Khoury and Yourougou's study includes the canola, rye, feed barley, feed wheat, flaxseed, and oats futures markets for the period March 1980 to July 1989. (Note: Winnipeg conducts the only flaxseed market in North America and the only canola, barley, and rye markets in the world.) Overall, the results indicate each of the five sources of volatility studied influence the volatility in each of the futures markets included in the study. Further, the results suggest that intervention by the Wheat Board reduces, but does not eliminate, the year, maturity, and trading session affects for wheat, barley, and oats; however, intervention has no impact on the month or contract effects.

Crain and Lee (1996) study the impact of 13 farm programs in effect from January 1950 to December 1993 on the volatility of wheat spot and futures prices. These programs include acts passed in 1949, 1954, 1956, 1961, 1962, 1964, 1965, 1970, 1973, 1977, 1981, 1985, and 1990. After dividing the programs into three groups (1/50 - 4/64; 4/64 - 12/85; and 12/85 - 12/93), regression results indicate that the second period experienced the highest spot and futures volatility while the first experienced the lowest. Crain and Lee believe the mandatory (acreage) allotments in the 1950's and early 1960's as compared to the voluntary programs in the mid and later 1960's contributed to the increased volatility of both spot and futures wheat prices. They conclude that seasonal volatility exists in the wheat market. Specifically, the harvest months, May through August, experience greater price volatility in both markets. However, government programs play a more significant role in price volatility than seasonality does. Finally, Crain and Lee believe the regression results provide clear evidence of the transfer of

⁹See explanations of each of these effects in the list of definitions at the end of Chapter 1.

volatility from the futures market to the spot market. This causal relationship has strengthened over the years and shows the strongest impact in period three. The authors suggest the implementation of more market-driven farm policies in recent years has caused this closer alignment of spot and futures prices. They also note that spot market volatility lags futures market volatility by up to 10 days.

Herendeen and Hallberg (1997) state that past agricultural price supports and production controls dealt only with symptoms of agricultural distress and not the causes; they also believe past programs reduced the output by low-cost U.S. producers while higher-cost Japanese and European producers faced few, if any, output restraints. Herendeen and Hallberg draw the following conclusions. First, agricultural output/prices exhibit greater volatility than aggregate output/prices— primarily because crop producers are price takers and weather affects production. Second, in the 1970s and 1980s, only a loose relationship existed between the aggregate business cycle and the agricultural business cycle; instead, the agricultural cycle closely followed the business cycle for raw materials producers. Third, the monetary and fiscal policy pursued by the U.S. (and other major countries) relating to real interest rates, changes in currency values and changes in overall world demand for basic commodities, provided the driving force behind the agricultural business cycle of the 1970s and 1980s. Fourth, the 1980s farm credit crisis resulted from an expansion of farm debt based on an increase in farm income due to a combination of falling interest rates and rising prices and yields; a subsequent rise in interest rates and fall in crop prices caused the value of land to collapse. Finally, a high correlation existed between real agricultural exports and the inverse of the value of the dollar; thus, domestic prices increased or decreased as the dollar rose or fell. Because

grains are both exported (in grain and oil form) and used as feed for livestock, which is also exported, changes in export prices have effects that extend beyond just the portion of the crop actually exported. Herendeen and Hallberg believe that future world demand for commodities, the value of the dollar, real interest rates, and the reaction of other major crop producing countries will determine whether U.S. government intervention in agriculture will diminish as a result of the FAIR Act.

Adam, et al. (2000) study the effects of a reduction in government deficiency payments on wheat producer's post-harvest marketing plans. (They do not evaluate the effect of a producer's use of futures contracts in pre-harvest marketing strategies.) They report that wheat producers did sustain a revenue loss from the elimination of these deficiency payments. They also find the deficiency payment program is no more effective than other approaches in reducing revenue risk associated with post-harvest grain storage. Adam, et al. believe some producers will compensate for the reduced revenue by purchasing futures contracts while others will sell all their wheat at harvest due to storage cost, risk aversion, etc.

In summary, McKinnon (1967), Khoury and Yourougou (1993), Crain and Lee (1996), Herendeen and Hallberg (1997), and Adam, et al. (2000) question the government's role in stabilizing commodity prices and indicate that at best, government intervention may reduce commodity price volatility. Additionally, Romer (1991) reviews the cyclical nature of production cycles over 95 years and the effect that government programs had on these cycles. Romer concludes government policy has been less than effective and the primary cause for changes in agricultural production relates to industry (agriculture) specific shocks. Because of the government's failure to effectively stabilize

commodity prices, the individual producer is faced with developing an income stabilization program. This dissertation attempts to determine whether daily futures prices for corn (soybeans) are consistently higher/lower than the related daily cash spot price (see Section 2) and whether a hedge ratio exists that minimizes price risk for the expected yield (see Section 3).

Section 2: Efficiency of the Commodity Futures Markets

According to Dorfman (1993), “The basic issue investigated in asset market efficiency studies is whether the future price of an asset can be predicted accurately enough to earn a forecaster/investor a risk-adjusted economic profit.” If the trader can earn a risk-adjusted economic profit, the market is not efficient; if the trader cannot earn a risk-adjusted economic profit, then the market is efficient because all currently available information has been incorporated into asset prices in a manner that prevents traders from earning excess profit through accurate forecasting. This statement applies not only to capital markets, but to commodity markets as well; thus, Section 2 discusses the efficiency of commodity futures markets. Subsection 2.1 reviews general studies relating to the efficiency of the commodity futures markets. Subsection 2.2 examines literature relating to seasonal and other anomalies while subsection 2.3 reviews cointegration literature. Subsection 2.4 presents literature relating to mean reversion of commodity futures prices. Subsection 2.5 addresses studies relating to risk premia, backwardation, and capital asset pricing models. Finally, subsection 2.6 reviews literature relating to the use of models to forecast expected price behavior.

Subsection 2.1: General Efficiency Studies

Previous studies have examined various aspects of futures market efficiency. An early study by Tomek and Gray (1970) finds that, all other things being equal, the allocative and forward pricing function of futures markets will be more reliable for continuous (corn or soybeans) than for discontinuous (Maine potatoes) inventory markets. Carrying continuous inventories results in daily price spread movements affecting all future delivery months “smoothly”; it also interacts with inventory adjustments and contributes to pricing efficiency.

Kofi (1973) develops a framework to assess the efficiency of futures markets and empirically compares the relative performance of Chicago wheat, Maine potato futures, cocoa, coffee, soybeans and corn. He finds, “. . . that futures markets perform their forward pricing function very well and that the correlation coefficient measures well the degree to which the spot (cash) price is predictable months in advance for a particular commodity.” Kofi also states, “The predictive reliability of a futures market improves as more accurate information on supply and demand becomes available.” He believes the market’s price setting function includes the market participant’s opinions about the significance of developing economic information in a changing world.

According to Taylor (1985), some researchers argue that speculators require a risk premium (i.e., a reward) when they buy a risky contract. Taylor states that this premium only exists when the commodity exhibits a positive daily return; he indicates the simplicity of standard autocorrelation tests (to identify these positive daily returns) makes them attractive to researchers, but conclusions based on these tests are unreliable due to

the false assumptions the tests require. The tests Taylor performs on various futures contracts suggest that risk premia may exist at the London markets but no evidence exists supporting the presence of risk premia at the Chicago and Sydney markets. Additionally, no futures prices experience significant average decreases on Mondays; however, currency futures rise on Wednesday and fall on Thursday due to the clearing system used. While the standard deviation for Monday's return is about 1.12 times the standard deviation on other days, it does not appear to increase systematically during the final six months of the futures contracts for the futures tested. Corn prices from 1963 to 1976 exhibit evidence of positive autocorrelation; i.e., the corn prices do not follow a random walk. However, this does not contradict the EMH if trading costs will exceed gross trading gains. Taylor indicates, however, that assessing the efficiency of any market is difficult because no one has described the evidence required to reject market efficiency conclusively. For example, using filter trading rules requires one to specify what a trader would compare to their trading results. Also, because of the unknown distribution of returns from the filter strategy, it is impossible to perform the proper significance tests. Finally, the selection of the filter parameter always presents a problem. Taylor's price-trend trading rules assessments indicate inefficiency in the sugar market; results in all other markets do not provide sufficient evidence to reject market efficiency.

The test of two hypotheses proposed to explain leptokurticity in futures price movements distributions, the stable Paretian and mixture of normals, suggests that dependence in price changes explains the leptokurtic distribution (Hall, et al. 1989). All tests applied to financial, metal, and agricultural futures using date sequence data show a leptokurtic distribution of the sums of the data; however, tests applied to randomized

data indicate a normal distribution of the sums of the randomized data. Hall, et al. suggest that because autocorrelation in futures prices is small, serial correlation of the variance provides the most likely reason for rejecting independence in price changes.

Johnson, et al. (1991) test for trading profits by applying a profit margin trading rule to the intercommodity spread of soybeans, soyoil, and soymeal (the soy complex). Previous hedging studies have tested this rule extensively. Johnson, et al. use a rule which requires initiating trades when a pre-specified implied profit exists (implied profit calculated from currently-quoted futures prices for the output of the production process and estimated production costs). Their findings suggest the (Fama) efficiency of nearby soy complex futures price spreads but the inefficiency of distant soy complex futures price spreads. Thus, soy complex futures spreads are not unbiased forecasts over longer time periods.

DeCoster, et al. (1992) concentrate on whether a nonlinear dynamic structure (and in particular, a chaotic structure) exists in the behavior of futures prices. If such a structure exists, one must question the possibility of a true random walk for asset prices. DeCoster, et al. use the correlation dimension technique to search for chaotic structure in daily futures prices for sugar, coffee, silver and copper. The sample size for each of the four commodities includes 4,000+ observations. The results suggest the presence of nonlinear structure in the data; advanced filtering techniques indicate the apparent structure does not simply reflect heteroscedasticity. DeCoster, et al. reject the noise explanation and a linear-structure-plus-noise explanation. This evidence of structure in futures prices raises new questions about the efficiency of futures markets since it creates a possibility that profitable, nonlinear trading rules may exist. However, remember that

because chaotic systems have sensitive dependence on initial conditions (i.e., minute errors in the observation of the state of the system at the beginning result in increasingly large errors as predictions go farther into the future), the long-term prediction of a chaotic system is impossible even if the form and parameterization of the system are perfectly known.

One model tests the explanatory capability of the standard rational expectations competitive storage model for such facts as skewness and the existence of rare but violent price explosions; however, the model does not provide a completely satisfactory explanation for the high price autocorrelation (year-to-year) found in more normal times (Deaton and Laroque 1992). The model explicitly recognizes that the market as a whole cannot carry negative inventories of commodities; this fact introduces non-linearity into any (predicted or actual) commodity price series. The results indicate the price behavior (from 1900-1987) for most of the 13 commodities analyzed conforms to price behavior predictions based on the theory of conditional expectations and conditional variances.

An examination of the U.S. oats market by Goss, et al. (1992) results in the development of a simultaneous rational expectations model. The model includes separate functional relationships for short and long hedgers, net long speculators in futures, holders of unhedged inventories, and consumers. The results of their tests provide support for the rational expectations hypothesis except in the case of short hedgers; the evidence supports the adaptive hypothesis for short hedgers. Goss, et al. find hedged stocks respond more to price changes than unhedged stocks and that net long and short speculative positions respond similarly to changes in futures prices. Results from a post-sample forecast of

cash prices based on the model do not provide sufficient evidence to reject the semi-strong form EMH for the U.S. oat market.

Gay, et al. (1994) examine futures price reactions to news stories discussing commodities exhibiting unusual trading volume during the previous business day. The results of this study indicate that headlines reflecting a bear market result in a greater price impact than headlines suggesting a bull market. Gay, et al. find prices fall and then reverse, with the reversal positively related to the magnitude of the opening price change, following “bear” headlines. Also, the opening price change magnitude displays a positive relationship with trading volume. These results suggest the implementation of trading rules could provide economic profit by exploiting the opening price of the contract.

Focusing on the estimation and testing of a price formation model, Deaton and Laroque (1996) acknowledge that speculative storage moderates supply and demand shocks. According to the authors, the existence of risk-neutral and profit-maximizing stockholders means expected futures prices cannot exceed current prices by more than the cost of storing inventories into the future; thus, whenever stocks are stored and carried over to the next period, prices in those periods are tied together. Speculative storage should also change the variability of commodity prices. When speculators expect the futures price to be sufficiently low, they will sell; this sale will “smooth” the effects on prices of negative supply and/or positive demand shocks. Thus, the authors believe speculative behavior should explain the highly correlated commodities prices observed in the data (their study uses the same data as that used in the Deaton and Laroque (1992) study). However, the results not only support a rejection of the hypothesis that speculator behavior could explain the high price autocorrelation, the results also reject the idea that

a combination of speculator activity and the driving processes of supply and demand could explain the autocorrelation. The authors conclude that while speculation may increase existing autocorrelation, it is not the only source of autocorrelation.

Efficient market theory implies market prices rapidly incorporate new information into both cash and futures prices as it becomes available. However, what value does the market assign to similar information received from different sources? Garcia, et al. (1997) test the informational value of USDA corn and soybean production forecasts as compared to an average of two private crop forecasts (one prepared by Conrad Leslie and the other by Sparks Companies, Inc. – both regarded as reliable and widely reported in the popular press) for the period 1971 - 1992. The results of three tests follow. First, the relative forecast accuracy test suggests the USDA and private forecasts have a similar level of accuracy. Second, the price reaction test shows an unanticipated component of USDA forecasts significantly affects corn and soybean futures prices to a greater extent than an unanticipated component of a private forecast. Finally, the willingness-to-pay test indicates traders would be willing to pay for advance knowledge of USDA forecasts. However, the results do indicate the informational value of the USDA forecasts has steadily declined since the mid 1980s.

Perrakis and Khoury (1998) develop and test a model to determine the theoretical and empirical implications of the existence of asymmetric information in the Winnipeg commodity futures markets. Results indicate information asymmetry (between hedgers and speculators) relating to known spot supplies exists in the canola and barley markets; however, the results show no evidence of information asymmetry in the oats market. Perrakis and Khoury believe the oat market results may have been caused by the influence

of the large trading volume in the Chicago market; in contrast, Winnipeg is the primary trading market for canola and barley.

Before 1986, the Chicago Mercantile Exchange (CME) required the settlement of all opening positions on feeder cattle futures contracts with physical delivery after the last trading day. Due to diminishing commercial interests, the CME replaced that system in 1986 with a cash settlement system. Chan and Lien (2002) use stochastic volatility models to determine if this change from physical delivery to a cash settlement system would improve the convergence of cash spot and futures prices and decrease the basis variability. Chan and Lien find both a reduction in basis and in basis variance as well as a change in the relationship between cash and futures prices. These results support the supposition that the change to a cash settlement would result in a more efficient futures market.

In summary, the results from the above studies generally support the weak form of the EMH and some results support the semi-strong form. However, Johnson, et al. (1991) indicate that while their results support weak-form efficiency of nearby soy complex futures price spreads, the results do not support weak-form efficiency for distant soy complex futures price spreads. Additionally, DeCoster, et al. (1992) find nonlinear structure in commodity price data and Gay, et al. (1994) note specific trends in the market's reaction to certain news stories. These results indicate some level of inefficiency may exist in the market. This dissertation attempts to determine whether daily corn (soybean) futures prices are consistently higher/lower than the related daily cash spot prices.

Subsection 2.2: Seasonal and Other Anomalies

Just as seasonal, day-of-week, and other anomalies found in the stock markets have important implications for stock market efficiency, these same types of anomalies impact decisions relating to the extension of trading hours, global trading, etc. for commodity futures contracts. A study by Anderson and Danthine (1983) attempts to clarify the meaning of the Samuelson hypothesis¹⁰ using a three trade date rational expectations model of *diverse* information. Their results indicate the resolution of large amounts of uncertainty creates volatility while the resolution of small amounts of uncertainty does not cause volatility. They also argue that when large amounts of uncertainty are resolved early in the life of a contract, then volatility will decrease as the maturity date approaches. Black and Tonks (2000) extend this test of the Samuelson hypothesis using a three-trade date rational expectations model of *asymmetric* information to distinguish between the effects of uncertainty and informational efficiency. Black and Tonks find that if a large amount of output uncertainty is resolved by the second trade date and if the market is informationally efficient, then volatility will decrease as the maturity date approaches thus violating the Samuelson hypothesis. However, for an informationally inefficient market, the Samuelson hypothesis will hold.

A study by Anderson (1985) examines whether the volatility of futures price changes per unit of time increases or decreases as the contract maturity approaches. He also reviews a theory which states that the resolution of significant supply or demand

¹⁰Samuelson (1965) theorizes that a negative relationship exists between maturity and futures price volatility; i.e., when the resolution of some uncertainty occurs when the time to contract maturity is distant the resolution will have little effect on the futures price, but it will have a large effect if the resolution takes place close to the contract maturity.

uncertainties will create volatility in the period the uncertainty is resolved. Using data for nine futures markets (including wheat, corn, oats, and soybeans), Anderson studies the volatility of daily price changes from 1966 to 1980. The results indicate a non-constant variance of futures price changes and that changes in variance follow a partially predictable pattern. Seasonality is the principal predictable factor for this pattern while the changing time to maturity is a secondary factor. Anderson indicates that hedgers guided by the portfolio hedging theory should adjust hedge ratios¹¹ seasonally.

An examination of soybean and U.S. Treasury bond futures contracts confirms a negative Monday and Wednesday effect for the bonds and a slight negative Monday effect for soybeans (Ferris and Chance 1987). Additional tests indicate the Monday effect results from Monday trading for the bonds. The results also provide evidence of higher day-to-day trading volatility on Monday relative to other trading days for both soybeans and bonds. Finally, volatility appears to be significantly higher (two to three times higher) during trading hours as compared to overnight and weekends for all trading on soybeans contracts and for all but the weekend/Monday trading for bonds.

Milonas (1991) questions whether seasonalities found in financial markets are also present in commodity markets. Although stock price indices lend themselves to time series analysis of the different seasonalities, commodity price indices do not because these indices are portfolios of commodities with and without a crop cycle. Therefore, if the crop related seasonality for each commodity is not controlled, the effect of the crop-related seasonality on the index cannot be assessed or identified. Also, commodity

¹¹Ratios of the covariance of futures and cash prices to the variance of futures prices.

indices are not diversifiable like stock indices due to unique seasonalities for each commodity. Three sources of seasonalities in commodities include the month effect, the year effect, and the maturity effect. In this study, Milanos tests for a fourth seasonality - the half-month effect.¹² Milonas tests five commodities; corn, wheat and soybeans (seasonal commodities) and soy meal and soy oil (non-seasonal ones). After controlling for month and year effects, all five commodities yield a positive average logarithmic return for the first half of the month and a negative return for the second half. However, the difference in the two half-month returns is only statistically significant for corn and wheat.

Stevens (1991) looks for evidence of a weather persistence effect on corn, wheat and soybean growing season price dynamics. He finds some evidence that during the growing season, corn, wheat, and soybean prices do not vary as a random walk. He hypothesizes that persistent growing season weather conditions arrive with some degree of momentum (suggested by the weather/climate literature) and induces similar momentum into commodity price dynamics.

The authors of one study use an alternative methodology to test for a maturity effect which controls for the effects of year, calendar month, and contract month (Galloway and Kolb 1996). The methodology requires calculating the monthly variances of daily futures returns for each commodity. Galloway and Kolb include price data from 1969 to 1992 for 45 commodities. The results provide strong support for a maturity effect in agricultural and energy commodities, but not in precious metal or financial

¹²Theory stating that the average stock return in the first half of the month is positive and significantly higher than for the second half of the month.

commodities. This indicates the maturity effect may play a significant role in the volatility of commodity prices for items which experience seasonal supply or demand.

Hennessy and Wahl (1996) test to see if futures contracts of sufficiently long durations allow producers to receive and act upon a pattern of futures price volatilities that emerges as the contract expiration nears; they show that seasonality arises from increasingly constrained supply and demand functions as the maturity date approaches and not from resolved uncertainty about the supply. In fact, the resolution of supply and demand uncertainty may increase, rather than decrease, price volatility; this runs contrary to the state variable hypothesis. The results indicate decisions made on the supply (demand) side make future supply (demand) responses less elastic; thus, supply or demand shocks occurring after a decision (such as the acreage to plant, number of contracts to buy, etc.) is made has more effect on the futures price than shocks before a decision is made.

A recent article by Goodwin and Schnepf (2000) documents sources of price variability in the U.S. corn and wheat futures markets. The results of both a conditional heteroscedasticity and a nonstructural vector autoregressive model indicate corn and wheat price variability is significantly related to the ratio of use to stocks, futures market activity, and growing conditions (strongest effect). Goodwin and Schnepf find that above-average crop conditions tend to produce lower levels of price variability; they also identify a strong seasonality in corn and wheat price variations with the highest variation peaks occurring in the summer.

To summarize, while Anderson and Danthine's (1983) test of the Samuelson hypothesis indicates that whether it holds or not depends on the timing of uncertainty

resolution, Black and Tonks (2000) find that whether it holds depends upon both the informational efficiency of the market and the timing of the uncertainty resolution. Both Anderson (1985) and Galloway and Kolb (1996) state that time to maturity affects the volatility of agricultural futures price changes; Anderson also indicates seasonality plays a primary role in any predictable pattern in the volatility of futures price changes. Additionally, Ferris and Chance (1987) find a Monday effect and higher volatility during trading hours as compared to overnight or weekends for soybeans, while Milonas (1991) notes a half-month effect for corn and wheat. Stevens (1991) indicates soybean, corn, and wheat prices do not vary as a random walk during the growing season; he attributes this to the incorporation of weather information throughout the growing season. Hennessy and Wahl (1996) believe seasonality in agricultural commodity futures contracts arises from increasingly constrained supply and demand functions as maturity approaches and not from resolved supply uncertainty. Finally, Goodwin and Schnepf (2000) find strong seasonality in corn and wheat price variation with the highest variation peaks in the summer (growing) months.

Subsection 2.3: Cointegration Tests

A number of researchers examine the prices of raw commodities and determine certain commodity prices exhibit a tendency to move together. Pindyck and Rotemberg (1990) examine average monthly cash prices (from April 1960 - November 1985) for wheat, cotton, copper, gold, crude oil, lumber, and cocoa. Their results indicate a statistically significant correlation between: gold prices and copper, crude oil, lumber, and cocoa prices; cotton prices and copper, lumber, and wheat prices; and between lumber prices and copper and cocoa prices. This co-movement of prices applies to unrelated

commodities in the sense that no cross elasticity of demand exists between the commodities; i.e., one would not purchase wheat in the place of cotton or crude oil in the place of gold to use in a production process. The identified co-movement exceeds anything that aggregate interest rate, inflation, exchange rate, or demand changes might explain. Pindyck and Rotemberg suggest this “excess” co-movement may result (to some extent) from herd behavior.¹³ To explain this “excess” co-movement, the authors present several possibilities. First, liquidity constraints may play a part; when the price of one commodity falls, it will lower the price of others because it hurts investors who are long in several commodities at the same time. Second, investors in different commodities may react similarly to non-economic factors such as a change in market psychology. Finally, commodity prices may include a large amount of high-frequency, mean-reverting noise. If this is true, then no macroeconomic variable nor a price change of any other commodity should explain a large percentage of price changes in any one commodity.

Peterson, et al. (1992) test the random walk hypothesis for cash prices over 15 years for 17 commodities, including corn, oats, wheat, soybeans, soybean oil, soybean meal, and cotton. The results of a variance ratio test reject the random walk hypothesis for daily agricultural commodity prices. The evidence suggests a positive serial correlation between successive price changes which underlying economic factors do not explain. The tests of agricultural commodities indicate a positive serial correlation in price changes over short and intermediate time horizons. This suggests many daily commodity prices may not react rationally to unexpected information or that the

¹³Pindyck and Rotemberg (1990) define herd behavior as the idea that “traders are alternatively bullish or bearish on all commodities for no plausible economic reason.”

adjustment process is not instantaneous because of transaction costs or because investors do not properly anticipate information revealed in a serially correlated fashion.

In their 1993 study, Fortenbery and Zapata examine the relationship of prices for two North Carolina cash markets and the CBOT futures market for corn and soybeans. Using aggregate data, the results support cointegration among all futures and cash markets considered. However, results reported by crop year indicate cointegration exists when minimal differences exist between the local and futures markets (i.e., widespread drought years vs. local drought) but does not exist otherwise. The results also indicate no profitable arbitrage opportunities exist between the two North Carolina markets or either local market and the CBOT.

In a 1994 article, Tomek (1994) comments on the Peterson, et al. (1992) analysis of the statistical properties of cash prices for 17 commodities. Tomek states that, "The important point is that cash prices for commodities should not be expected to follow a random walk. Thus, this model is not a useful benchmark for measuring the efficiency of cash markets for commodities." He indicates good reasons exist for the autocorrelation of commodity prices; reasons include the supply/demand relationship for commodities and dynamics associated with transaction costs as new information creates changes in prices. Also, he disagrees with Peterson et al.'s belief that one could use some component, independent of the underlying fundamentals, to predict futures prices. Tomek states that any systematic patterns probably reflect transaction costs or some other market fundamental in complex markets. He indicates a need for additional research concerning the cost/benefit of improved data collection to help explain these market fundamentals.

The statistical relationship between world and U.S. sugar futures contracts traded on the CSCE was examined by Arguea and Harper (1994). The results indicate that when the U.S. imposes tariffs on imports, the world and U.S. sugar prices exhibit strong linkages; however, when the U.S. operates under a quota program (thus insulating the U.S. from world price changes), linkages are not evident. World prices appear to lead U.S. prices under the tariff period but the U.S. market does not appear to influence world prices under either the quota or tariff period.

Another author uses cointegration techniques to test market efficiency in the live cattle, frozen orange juice concentrate, cocoa, copper, and corn spot and eight week futures price markets. Beck (1994) permits the presence of risk premia in this study. Although the empirical results provide evidence that inefficiency exists in all five markets at certain times, no market rejects efficiency all the time. Results from the error correction model (ECM) indicate that situations where the ECM rejects unbiasedness correspond to those cases that reject efficiency as well; this indicates that inefficiency, rather than the presence of risk premia, causes the rejection of unbiasedness in commodities futures prices.

Leybourne, et al. (1994) present a conceptual framework for identifying and testing the excess co-movement hypothesis; this framework proposes a rigorous definition of co-movement which says that prices co-move if those prices are cointegrated with a positive cointegration parameter. Leybourne, et al. test 12 commodities, including cotton, sugar, and wheat, for co-movement. Since the results indicate co-movement only between lumber and cocoa, these tests reject the idea of widespread, excess co-movement between commodities.

Karbuz and Jumah (1995) examine the long-run relationship between futures and spot prices of cocoa and coffee on both the CSCE and the London Fox for the 12-year period from 1980 to 1991. The results point to cointegration between the prices of coffee and cocoa in the long run. The results also support the law of one price (LOP) for cocoa spot and futures prices; however, the results provide only weak support for the LOP for coffee futures. Karbuz and Jumah believe weak support for the LOP for coffee futures results from the difference in the type of coffee beans traded on the CSCE (arabica beans) versus those traded on the London Fox (robusta beans).

Brenner and Kroner (1995) incorporate the use of a no-arbitrage, cost-of-carry asset pricing model and show that the existence of cointegration between spot and futures prices depends on the time-series properties of the cost-of-carry. The authors provide an overview of recent publications relating to cointegration in the commodity and foreign exchange markets. Brenner and Kroner also examine four of the existing tests for the unbiasedness hypothesis in the financial markets and use the cointegration results to show why these tests reject unbiasedness.

A study investigating the long- and short-term relationships between six commodities traded on the CBOT (soybeans, soybean meal, soybean oil, corn, wheat, and oats) extends from January 1981 through October 1991 (Malliaris and Urrutia 1996). The results indicate cointegration of the time series of prices. The error correction model strongly supports statistically significant relationships between each of the commodities tested but finds no short-term causality. Malliaris and Urrutia believe this dependency in prices between commodities relates to the ability to substitute one grain for another (especially for feed grain purposes) and the complementary properties of the grains (i.e.,

the nutrients in corn complement the nutrients found in soybeans). The authors state, “The very essence of futures markets is the opportunity they offer for price discovery.” Malliaris and Urrutia indicate the price discovery function of one commodity futures contract also provides relevant information for other related commodity futures contracts.

Hudson, et al. (1996) compare Southwest region producer spot prices of cotton to cotton futures prices to examine the cash/futures price relationship. The study includes a price comparison for the four-year period from 1989 through 1992. Cointegration test results indicate no consistent relationship between cash spot prices and futures prices. The tests reveal cointegration for 1989 and 1992; however, no cointegration is found for 1990 and 1991. In the presence of cointegration, the results of the error correction causality model find that the futures market leads the cash market.

Using monthly cash prices for 21 commodities (including wheat, corn, rice, soybeans and cotton), Barkoulas, et al. (1997) test for long memory across commodity spot prices. Because test results confirm fractional orders of integration for soybeans, copper, and tea, the authors believe it is possible to construct time series models to take advantage of these fractional integers. The results also indicate the fractional orders may vary among the different series; this may occur because different processes generate price movements for different commodities (i.e., annual crops experience shorter-run processes due to weather conditions while minerals experience both shorter-run processes linked to business cycles and longer-run processes due to exploration and capital issues). Third, the authors conclude the existence of fractional dynamics in spot prices makes the use of linear price models questionable and indicate the need to develop a nonlinear price model to account for fractional behavior in prices. Barkoulas, et al. believe the discovery of a

long memory property in a futures series may reflect statistical properties of other factors creating the spot prices and that commodity market processes which contain long-term dependence, in fact, generate these factors. If true, this reopens the debate of pricing efficiency and market rationality in commodity futures markets. Finally, although Crato and Ray's (2000) reexamination of the data set used by Barkoulas, et al. finds no evidence supporting the existence of long memory in futures' returns,¹⁴ their results do support the existence of long-memory behavior in the volatility of futures' returns.

Fortenbery and Zapata (1997) evaluate the price linkages between futures and cash markets for cheddar cheese to determine whether one market dominates the other in the price discovery function and the overall pricing behavior of the markets. The results of cointegration tests provide no support for a stable long-run relationship between cash and futures markets for cheddar cheese. This may result from the relative immaturity of the market; the test period coincides with the beginning of futures trading in cheddar cheese. The authors note that two other new futures markets (fertilizer products) became closely linked with the respective cash markets within one year. They conclude it does not appear reasonable to trade price risk for basis risk in the cheddar cheese market as a risk reduction strategy. However, an extension of this study by Thraen (1999) finds the cointegration parameters in the cheddar cheese markets converge after approximately 126 weeks of trading (i.e., approximately two and one-half years), thus, providing support for efficiency in the cheddar cheese market.

¹⁴Long memory is a process which shows autocorrelation between asset returns that decline slowly and asymptotically following a hyperbolic path.

In one study, Chaudhry and Christie-David (1998) investigate the long-run stochastic properties of informationally linked futures contracts in diverse groups such as soft commodities (sugar, cocoa, coffee, orange juice), grain and oilseeds (wheat, soybean oil, and oats), livestock (cattle, hogs, and pork bellies), and other non-agricultural commodities. Tests reveal the presence of cointegration within the soft commodities group and several of the non-agricultural groups. The results provide weaker evidence of cointegration within the grain and oilseeds group and the livestock group. Cointegration tests also find evidence supporting cointegration among the three agricultural groups. Finally, the results indicate the presence of at least one cointegrating vector between the soft commodities, grains and oilseeds, livestock groups and the Commodities Research Bureau index.

Yang and Leatham (1998) examine the EMH as it relates to major U.S. grain markets by testing for cointegration between the daily cash prices of corn, oats, wheat, and soybeans. The results of both bivariate and multivariate cointegration analyses provide no evidence of cointegration between any of the cash grain prices.

Another author proposes a regime switching model of spot prices (Chow 1998). Chow shows that Monte Carlo experiments which test for cointegration and estimates of the cointegrating vector may be biased when a sample has infrequent changes in regime. After consideration of these items, the results support the cointegration of spot and futures prices; these prices move together in the long-run.

Malliaris and Urrutia (1998) conduct tests of cointegration between price and volume for six commodity futures contracts (corn, wheat, oats, soybeans, soybean meal, and soybean oil) for the period January 1981 through September 1995. The data supports

cointegration between price and volume with a stronger long-run relationship from price to volume. This suggests that trading volume tends to follow and adjust to price in the long-run. The error correction model supports long-run bidirectional causality between price and volume. The results also indicate that, of three factors tested (time trend, price, and volatility), only price volatility produces a statistically significant impact on trading volume. Finally, Malliaris and Urrutia find that price volatility significantly impacts volume volatility.

In a recent study, Kellard, et al. (1999) test for unbiasedness and efficiency in futures markets using a cointegration methodology. According to the authors, an efficient commodity market will yield futures prices that are an optimal forecast of the expected future spot price except to the extent that a random unpredictable zero-mean error exists. Their results suggest a cointegration of spot and futures prices in the soybean, live hog, and live cattle markets. However, this long-run cointegrated relationship may not hold in the short run since a lagged difference in the spot and futures prices as well as the basis can explain some changes in the spot price. Additional tests support the efficiency of the soybean market and the inefficiency of the live cattle market; although the hog market also exhibits inefficiency, the results indicate it is less inefficient than the live cattle market.

Goodwin and Piggott (2001) evaluate regional corn and soybean markets in North Carolina for spatial linkages and daily price dynamics. They confirm a tight integration of these markets; price adjustments generally occur within fifteen days. Goodwin and Piggott also indicate transactions costs may form a neutral band that results in a well integrated market even though the market prices are not directly linked.

In their study, Yang, et al. (2001) allow for the compounding factor of stochastic interest rates and focus on the price discovery performance of futures markets for both storable and nonstorable commodities. Their findings support the theory that futures prices provide an unbiased predictor of future cash prices in the long run for the storable commodities tested (corn, oats, soybeans, cotton, and pork bellies); the results indicate that futures prices lead cash prices in the long run. However, futures prices do not provide an unbiased predictor of future cash prices for most livestock markets and thus, producers should use futures prices cautiously when making production decisions.

According to Thompson, et al. (2002), the degree of spatial efficiency between commodity markets has important implications for market operations and policy reforms. They investigate the degree of spatial equilibrium between three European Union (EU) wheat markets and how policy reforms affect the speed of adjustment between the markets long-run price relationships. Thompson, et al. use a seemingly unrelated cointegration test (SUADF) and a seemingly unrelated error correction model (SURECM). The results from these tests indicate that spatial equilibrium exists in the EU wheat markets and that policy liberalizing reforms allow a more rapid convergence of world prices.

Using both cointegration and error correction models, McKenzie and Holt (2002) test the live cattle, hogs, corn and soybean meal futures markets for unbiasedness and market efficiency. Although their results support both unbiasedness and efficiency in all markets in the long run, they find some pricing biases (i.e., normal backwardation) and inefficiencies in the short run in the corn and live cattle futures markets.

In summary, tests of cointegration between cash and futures markets for various agricultural commodities yield mixed results. While Pindyck and Rotemberg (1990) and Barkoulas, et al. (1997) find correlation between commodities with no cross elasticity of demand, other results generally support cointegration only between related commodities (i.e., substitute commodities). Examples include: Kurbuz and Jumah's (1995) results indicate long-run cointegration of coffee and cocoa prices; Malliaris and Urrutia (1996) find cointegration between grain and soy complex prices; Chaudhry and Christie-David (1998) provide weak evidence of cointegration within the grain and oil seeds group and between this group and other agricultural product groups; Chow (1998) finds cointegration between spot and futures markets; and McKenzie and Holt (2002) indicate that while the corn, soybean meal, hog and live cattle futures markets are all unbiased in the long run, the corn and cattle markets show evidence of bias (i.e., normal backwardation) in the short-run. Crato and Ray's (2000) results do not support the existence of long memory in futures' returns but their results do support the existence of long-memory behavior in the volatility of futures' returns. However, Leybourne, et al. (1994) reject widespread excess co-movement in agricultural commodity prices because only two of 12 commodities tested (cocoa and lumber) provide any evidence of co-movement.

Other studies center on the cointegration of cash and futures market for specific commodities and these studies also provide mixed results. For example, Fortenbery and Zapata (1993) find cointegration between the futures and cash markets for both soybeans and corn using aggregate data while individual year data does not support cointegration; Hudson, et al.'s (1996) results do not provide evidence of consistent cointegration of the

(southwest) cotton cash and futures markets; Fortenbery and Zapata (1997) find no cointegration of cash and futures markets in the initial years of the cheddar cheese futures market but Thraen's (1999) extension indicates the markets cointegrated after trading for 126 weeks; and Kellard, et al.'s (1999) results provide evidence supporting the long-run cointegration of the soybean spot and futures markets. Goodwin and Piggott (2001) find tight integration of the North Carolina soybean and corn markets while Yang, et al. (2001) indicate that the futures market provides an unbiased predictor of future cash prices for storable commodities but not for livestock. Finally, Thompson, et al. (2002) find that EU wheat markets display spatial equilibrium and that liberalizing policy reforms contribute to a more rapid convergence of world wheat prices.

As suggested above, most of the studies support cointegration of soybean and corn prices. If this is true, this dissertation should find that if daily corn futures prices are consistently higher/lower than the related daily corn spot cash prices, then the same (or close) opportunities exist for soybeans. Likewise, in the presence of cointegration between these commodities, if daily corn futures prices are not consistently higher/lower than the related daily corn cash spot prices, then daily futures prices for soybeans would also not be consistently higher/lower than daily soybean cash spot prices.

Subsection 2.4: Mean Reversion and Monte Carlo Techniques

According to Dorfman (1993), most studies pose the null hypothesis of an efficient market as a statistical relationship that asset prices follow a random walk. If asset prices follow a random walk, then investors cannot profitably predict prices; the alternative then indicates that the time series of prices tends to exhibit mean reversion.

Mean reversion requires the rejection of the EMH because investors observing any deviation from the mean would buy/sell the asset currently to allow the realization of a profit when the asset price reverts to the mean. Dorfman's results from a nonparametric Bayesian test rejects market efficiency; additionally, he finds the futures market does not exhibit more or less efficiency as the contract nears expiration.

The authors of one mean reversion study use price data from futures contracts with varying delivery horizons to determine if investors expect futures prices to revert. The methodology of the Bessembinder, et al. (1995) study focuses on the relationship between the slope of the futures term structure (across various delivery dates) and price levels on a given trading date. If an inverse relationship exists between prices and the futures slope, it indicates investors expect a mean reversion in spot prices. The results of tests relating to metals, crude oil, and agricultural commodities indicate mean reversion in spot prices occurs and that the reversion arises solely from positive co-movement between prices and implied cash flow yields.

Irwin, et al. (1996) test for mean reversion in corn, soybean, wheat, live hog and live cattle futures prices. They question the statistical evidence in previous studies because the studies do not explore the small sample properties of test statistics; in fact, recent studies examining the possibility of mean reversion in stock prices indicate that small sample bias may trigger most, if not all, of the rejections of the EMH. This result occurs because assumed asymptotic distributions poorly approximate actual small sample distributions. Irwin, et al. apply a regression test of mean reversion to changes in commodity futures prices; they also use Monte Carlo simulations to generate the small sample distributions of regression parameters and test statistics (based on a null

hypothesis of no predictability in futures prices). They test data for the period January 1975 - September 1992 for all five commodities. The authors find that although the original (or asymptotic - because the parameter and covariance estimates were only asymptotically consistent) regression results strongly support mean reversion, the Monte Carlo regression results do not. Under the asymptotic regression, four of the five Bonferroni joint test statistics are significant at the 5% level. However, using the Monte Carlo regression results, none of the Bonferroni test statistics are significant at the 5% level. These results support the EMH.

A hedging model developed by Zhou (1998) makes two assumptions. First, it considers only commodities that are indispensable goods (i.e., in periods of low supply, the market will pay a higher price to ensure an adequate level of consumption). Second, the model assumes producers have a liquidity constraint; their trading losses in the futures market cannot exceed a pre-specified level. The model's results indicate: 1) liquidity constraints may cause mean reversion in futures prices which then makes speculation profitable; 2) speculation in the market then tends to make volatility an increasing function of the price level; and 3) when the government provides a price subsidy, the effect of the subsidy depends on the liquidity constraints faced by producers participating in the market. When producers do not face a trading loss liquidity constraint, the subsidy causes a negative expected return on the futures price and reduces overall price volatility; this effect occurs most commonly when the futures price just equals or is slightly below the governmental price subsidy level.

In summary, Dorfman's (1993) nonparametric Bayesian test and mean reversion tests performed by Bessembinder, et al. (1995) and Irwin, et al. (1996) find mean

reversion in certain commodity prices and thus, they reject efficiency in these markets. However, an additional Monte Carlo test performed by Irwin, et al. indicates that mean reversion does not occur. Finally, Zhou (1998) suggests that when mean reversion occurs, liquidity constraints may cause it. If commodity markets are not efficient, then daily corn (soybean) futures prices may be consistently higher/lower than the related daily cash spot price.

Subsection 2.5: Risk Premia, Backwardation and Asset Pricing Models

To determine whether futures prices represent an unbiased or biased forecast of future cash spot prices, a number of studies compare futures prices for a given commodity (for a specific contract month) to the subsequent cash spot price. An early study reported by Telser (1958) tests for a trend in wheat and cotton futures contract prices. This study spans prices from 1927-1954 (May wheat) and from 1926-1954 (December cotton). His results reject the theory of backwardation and support the idea that no trend exists in futures prices.

Dusak (1973) calculates individual commodity betas for five contracts each for wheat, corn, and soybeans by regressing commodity returns on the S&P 500 stock portfolio. She determines that each of the betas does not differ significantly from zero. Dusak interprets these results as supporting the hypothesis that futures prices provide an unbiased estimator of the future spot price.

A study conducted by Bodie and Rosanksy (1980) examines the distribution of returns on 23 commodity futures contracts (17 agricultural contracts) for the 27-year

period from December 1949 through November 1976. The results indicate the contracts yield a positive mean excess return (above the risk-free rate on T-bills) which lends support to the normal backwardation hypothesis. However, the relationship between these means and the calculated corresponding beta coefficients does not support the conventional form of the capital asset pricing model (CAPM). Also, the mean rate of return on a diversified commodity futures portfolio provides a return well in excess of the average risk-free rate and provides a return close to the mean and variance of the return earned on the S&P 500 common stock portfolio. If the investor combines an investment with a ratio of 60% in a stock and 40% in a commodity portfolio, he could achieve a reduction in variance without a corresponding decline in the mean return.

Hazuka (1984) uses a consumption oriented CAPM to develop a linear relationship between consumption betas and risk premiums. He finds that the model used for nonstorable commodities (livestock, eggs) has great explanatory ability while the models for seasonal storable commodities (wheat, corn, soybeans, etc.) and non-seasonal storable commodities (copper and silver) do not have any explanatory ability.

Another study employs a nonparametric test to examine returns to speculators in wheat, corn, and soybeans futures (Chang 1985). The results yield evidence inconsistent with the hypothesis that commodity futures prices provide unbiased estimates of the corresponding future spot prices; instead, the results support the theory of normal backwardation. The results also indicate risk premiums exist in different degrees in different markets at different times and the risk premiums are more prominent in recent years. Finally, Chang indicates that "large wheat speculators" possess some superior forecasting ability and that the market rewards this skill.

Jagannathan (1985) uses the ICAPM to analyze prices (based on monthly consumption data) for individual corn, wheat, and soybeans futures contracts; he rejects the model. Reasons for rejecting the model include: the 1) asymptotic inference theory may not be justified due to the small sample size (monthly prices for the period 1960 - 1978); 2) agents may not possess/have access to the same information set; 3) model assumes a utility function which is time separable and that no shocks to preferences occur; 4) agent may not have frictionless access to markets as assumed by the model; and 5) model ignores durable goods consumption due to difficulties associated with measurement.

According to Fama and French (1987), while no controversy exists regarding the theory of storage,¹⁵ little agreement exists on whether futures prices contain expected premiums or whether futures prices provide unbiased estimates of future spot prices. Fama and French use both models in their study of the behavior of prices for 21 different commodities. They determine that, as a result of the availability of more powerful statistical tests, it is easier to detect the response of futures prices to storage cost variables than to obtain evidence that futures prices contain premiums or that futures prices forecast future expected spot prices. Their results indicate that soybean and animal product futures prices show some evidence of forecast power. Fama and French also provide limited evidence that corn, wheat, and cocoa futures prices include an expected premium.

In contrast to Bodie and Rosansky (1980), Murphy and Hilliard (1989) state that high positive excess returns on long commodity futures before 1974 may actually

¹⁵Explains the difference between current spot and futures prices as the interest foregone due to storage/warehousing cost and as a convenience yield on the inventory (Fama and French 1987).

represent compensation for the large size and indivisibility of commodity futures contracts. These characteristics make it impossible for many investors to diversify the unsystematic risk associated with an investment in commodity futures contracts. The returns may also provide compensation for tax disadvantages related to an investment in commodity futures versus stocks. With stocks, investors can delay tax consequences associated with stock price increases by holding, instead of selling the stock; in contrast, commodity futures contracts have a fixed life and when the contract expires, investors must recognize any gains or losses immediately. However, the data indicates the excess returns for indivisibility and tax disadvantages disappeared after 1974, perhaps because mutual fund investments in commodity futures became available (Murphy and Hilliard 1989).

Kolb (1992) first tests 29 commodities and finds seven that support the theory of a risk premium. Three commodities exhibit contango (lumber, heating and crude oil) while four show backwardation (live cattle, feeder cattle, live hogs, and orange juice).

Beck (1993) tests prices for live hog, live cattle, silver, soybeans, and orange juice concentrate at 8, 12, 24, and 40 week forecast horizons using an intertemporal hedging model. The results provide evidence of significant constant risk premia for cattle and soybean prices; for all forecast horizons except the 8-week one for orange juice; for all horizons except the 12-week one for silver; and at the 12-week horizon for hogs. Generally, the constant risk premium size decreases for shorter horizons.

Bailey and Chan (1993) use systematic factors to explain variation in the spread between commodity spot and futures prices for metals, agricultural crops, livestock, lumber, and food products. The authors believe common elements should affect the basis

variations across different commodities; they state that futures prices include not only the cash price, but also a risk premium for bearing the systematic risk associated with carrying the futures position. The results: 1) indicate the default yield spread in the bond market and the stock market dividend yield explain a large portion of the common futures market variation in basis; and 2) suggest macroeconomic risks which affect stock and bond markets also affect the risk premiums associated with commodity futures markets.

Cooper (1993) addresses problems with empirical rejections of the ICAPM. The methodology employed replaces the marginal rate of substitution with an index portfolio; this replacement avoids the use of noise and infrequently reported consumption data. The commodities tested include corn, cocoa, soybeans, wheat, and several other non-agricultural futures contracts. Contrary to Jagannathan's (1985) rejection of the model, the results of this study demonstrate the superiority of intertemporal modeling of futures and forward risk premia as opposed to single-period modeling for all futures contracts tested. According to Cooper, these results suggest previous rejections or other problems with ICAPM may relate to restrictive utility assumptions or poor consumption data.

Bessembinder (1993) evaluates whether asset portfolios and portfolios including futures lie on the same estimated security market line (SML) using a cross-sectional regression T^2 test. Bessembinder tests a comprehensive cross section of 22 different futures contracts, including financial, foreign currency, agricultural and metals futures. The evidence indicates a zero mean return for commodity futures. The three hypotheses tested include:

- 1) expected futures returns are a linear function of futures' systematic risk - which Bessembinder rejects using a single beta

(simple regression of monthly returns against CRSP value-weighted index returns) but does not reject when using multiple betas (estimated by multiple regression of monthly futures returns on CRSP value-weighted index returns and six macroeconomic variables);

- 2) the linear function has a zero intercept - which Bessembinder does not reject; and
- 3) the risk premia equals those provided in asset markets.

The results require rejecting the joint hypotheses of a zero intercept, linearity, and risk premia equal to that provided by the asset market regardless of whether the model includes a single or multiple betas. Thus, Bessembinder concludes that portfolios containing futures do not lie on the same estimated SML as asset portfolios.

Kenyon, et al. (1993) use recent data to evaluate the performance of spring corn and soybean futures prices in forecasting harvest prices. Their results indicate that while the December corn and November soybean futures prices in the spring (i.e., planting time) provide a good indication of harvest prices from 1952 - 1968, they were not good forecasters from 1974 through 1991. Kenyon, et al. indicate that one should consider futures prices as forward prices rather than price forecasters.

Deaves and Krinsky (1995) extend a previous study by Kolb (1992) relating to seven commodities that support the theory of a risk premium; heating oil, crude oil, and lumber exhibit contango while live cattle, feeder cattle, live hogs, and orange juice show backwardation. Deaves and Krinsky retest the same seven commodities using an additional five years of data to determine if the commodities continue to exhibit contango

or backwardation properties. Although they find that livestock commodities continue to fit the backwardation model, the rest of the commodities do not. Deaves and Krinsky question whether any commodity futures, other than livestock futures, contain consistent risk premiums.

The authors of a recent study analyze “differences in one-period risk premia for futures contracts with different maturities” (de Roon, et al. 1998). The results indicate heating oil has constant and negative risk premia which implies an upward-sloping term structure of yields. Tests of the German Mark do not provide evidence which supports rejecting the hypothesis that the risk premia differs from zero. Gold and soybean futures returns depend on the slope of the expected futures term structure; i.e., a long-term contract provides a higher (lower) expected return relative to short-term contracts when a larger (smaller) spread exists between the long- and short-term contracts. Mixed results for live cattle futures and for gold and soybean futures indicate that the one factor model used in this study does not explain the regression evidence or the average slope of the yield curve.

Zulauf, et al. (1999) reexamine the forecasting performance of spring prices for December corn and November soybean futures contracts using a price-level and a percent-change model. While the price-level model indicates spring prices for November soybean futures contracts provide a biased forecast, the percent-change model indicates spring prices for both November soybean and December corn futures contracts provide unbiased forecasts. Zulauf, et al. state, “If futures markets provide unbiased forecasts, individual producers can use them to guide production decisions without on average expecting to suffer financial losses due to changes in prices between planting and harvest. By contrast,

if the futures markets provide biased forecasts, then individual producers may suffer financial losses from misallocating resources unless they simultaneously hedge production.” Finally, Zulauf, et al. suggest that because both models have relatively low R^2 s (i.e., explained variance) for the 1973-1997 period, producers should search for additional information because futures markets do not predict future spot prices with any degree of accuracy.

Although many asset pricing models use a constant expected return to evaluate the presence of a risk premium, Miffre (2000) allows for variation through time in expected returns. His results strongly support the normal backwardation and contango theories; in particular, the results strongly support normal backwardation for corn, soybeans, and wheat. The tests provide little support for the hypothesis “that the futures price is an unbiased estimate of the maturity spot price,” but provide strong evidence of risk transfers from hedgers to speculators.

In de Roon et al.’s (2000) study, the authors present a model of the futures risk premia that identifies hedging pressure variables as well as the covariance of futures returns with the market (S & P 500) return. The model includes hedging pressure within a specific futures market (i.e., corn) and other related markets (i.e., other grain markets related to corn). de Roon et al. find, after controlling for market risk, that hedging pressure variables significantly affect futures returns even when price pressure effects are also controlled. These hedging pressure effects also impact returns on the underlying assets.

After estimating the joint value of timing and location delivery options on corn futures contracts, Hranaiova and Tomek (2002) use that value in regression models to see

how much these options influence basis variability on the first day of the futures contract maturity month. They also use econometric models to “see if the estimated implicit options values are useful in improving the forecasts of basis convergence over the 2-month period prior to maturity.” Hranaiova and Tomek’s results indicate the joint value of the delivery options does explain some of the basis variability; however, the use of this variable in basis convergence forecasts did not significantly reduce basis risk.

Finally, Sorensen (2002) uses both time-series and cross-sectional characteristics of corn, soybean, and wheat prices to evaluate seasonality in commodity prices. His results suggest that all futures contracts for soybeans and wheat display normal backwardation. However, while long contract maturities for corn also exhibit normal backwardation, short contract maturities for corn display contango properties. Sorensen also finds that an empirically significant negative relationship exists between convenience yields and inventory levels.

In summary, previous research yields mixed results regarding the presence of risk premia in commodity prices. Telser (1958) rejects backwardation; in contrast, results from Bodie and Rosansky (1980), Chang (1985), Fama and French (1987), Kolb (1992), Beck (1993) and Sorensen (2002) all support the theory of backwardation for certain commodities. An extension of Kolb’s study by Deaves and Krinsky (1995) finds that only one of the original four commodities exhibiting backwardation continues to provide evidence of the presence of risk premia in futures prices. However, Murphy and Hilliard (1989) report that high excess returns may actually represent premia for the large size and indivisibility of futures contracts and tax disadvantages associated with investments in commodities vs. stocks; the appearance of commodity mutual fund investments after 1974

has caused these disadvantages to disappear. Finally, Miffre (2000) reports strong evidence supporting normal backwardation and contango theories when he uses an asset pricing model which allows for variation through time in expected futures returns.

Studies focusing on the use of pricing models also provide mixed results. Dusak (1973) finds calculated betas do not differ significantly from zero and thus concludes that futures prices provide unbiased estimates of future spot prices. While Fama and French (1987) indicate soybean futures provide some forecast power of future spot prices, Kenyon, et al. (1993) and Zulauf, et al. (1999) indicate futures prices are not good indicators of future spot prices for corn or soybeans. Jagannathan (1985) rejects the ICAPM for corn, wheat, and soybean futures contracts while Cooper (1993) accepts the ICAPM for modeling futures and forward risk premium. Hazuka's (1984) test of a model based on a linear relationship between consumption betas and risk premiums has no explanatory ability for seasonable storable commodities such as wheat, corn, or soybeans. Bailey and Chan (1993) indicate the bond market default yield spread and stock market dividend yields explain a significant portion of futures market basis variation; this indicates macroeconomic risks affecting stock and bond markets also affect commodity market risk premiums. Bessembinder (1993) finds that portfolios containing futures do not lie on the same estimated SML as asset portfolios. According to de Roon, et al. (2000), hedging pressure variables from the "own" futures market as well as related futures markets have a significant effect on both futures returns and returns on the underlying assets. Finally, Hranaiova and Tomek (2002) state that the use of estimated joint values of timing and location delivery options on corn futures contracts does not significantly reduce basis risk.

The mixed results regarding the possible presence of risk premia in futures prices have an important implication for this dissertation. If futures prices contain risk premia (i.e., the activity of speculators in the market supports the presence of risk premia), then daily futures prices should be consistently higher/lower than daily cash spot prices.

Subsection 2.6: Forecasting and Trading Strategies

Many studies develop models to forecast prices so that producers can make marketing decisions, processors can make purchasing decisions, and speculators can make investment decisions. Turner, et al. (1992) state that the ability to forecast futures prices represents an integral part of a profitable commodity futures trading strategy. However, most technical strategies rely on price or some factor derived from price and do not incorporate other information such as trading volume or open interest. Turner, et al. use a Markov indicator based on historical probabilities of moving from one state to all other possible states.¹⁶ The results provide evidence supporting correlation in the indicated market elements. Thus, information regarding open interest or trading volume may assist traders in forecasting price change directions in futures contracts.

According to Borensztein and Reinhart (1994), studies stressing a structural approach to commodity price determination find that the state of the business cycle in industrial countries and the real exchange rate of the U.S. dollar (two demand-side variables) explain much of the variation of commodity prices. However, after 1984, the economy in many industrial nations strengthened and yet commodity prices remained

¹⁶Turner, et al. (1992) define a state as, “combinations of directional changes in price, volume, and open interest during a given interval of time.”

weak. Therefore, Borensztein and Reinhart incorporate commodity supplies and Eastern European/Soviet output into a price forecast model. This revised model outperforms a random walk forecast for longer-term horizons (5-31 quarters) and correctly forecasts major price turning points.

A study by Leuthold, et al. (1994) tests the forecasting ability of large traders in the frozen pork bellies futures market by looking for consistent forecast ability and for “big hit”¹⁷ ability. They find that a subset of large elite traders possess significant forecasting ability; not only are these elite traders able to accurately forecast the direction of price changes consistently, but they also take the “correct” position when large price changes occur.

Ntungo and Boyd (1998) test the application of a neural network as a commodity trading method by comparing forecast results to results obtained from a more traditional ARIMA model for corn, silver, and deutsche marks.¹⁸ Both models produce positive returns at approximately the same level; the authors believe the trading rule used may contribute to these positive results. Another contributing factor to the positive returns may be disequilibrium in the various markets. Ntungo and Boyd indicate that because neural networks require subjective estimates for various parameters and estimation procedures, no two studies will produce the same results.

An analysis of the effect of including stochastic interest rates in a futures price forecast model indicates the forecasted futures price will differ from futures price

¹⁷Traders take larger positions when they expect larger price changes.

¹⁸Computing structures modeled on the brain are called neural networks. They provide nonlinear methods for evaluating pattern recognition, classification, and prediction.

forecasts produced by a two-factor stochastic convenience yield model (Hilliard and Reis 1998). The price difference depends on volatility of the interest rate process, correlation between spot prices and interest rates, and correlation between interest rates and convenience yields. However, the forward price forecasted by a two-factor model does not differ significantly from the price forecasted by a three-factor model which includes the stochastic interest rate. Finally, Hilliard and Reis find that jumps in the spot price process do not significantly affect forward or futures prices.

In a recent study, Elfakhani, et al. (1999) examine whether thin trading in the Canadian canola and feed wheat futures markets creates profit opportunities for traders as compared to high trading volume in soybean oil and wheat futures at the CBOT. To test the weak and semi-strong forms of the EMH, Elfakhani, et al. construct a model (both full and reduced) to predict the next day futures prices. A comparison of forecasted prices and benchmark prices (i.e., actual opening or closing prices) identifies possible over- or undervalued futures. Trades are initiated based on the identified opportunities using both a confidence interval and a percentage change filter trading rule. After consideration of transaction costs, the authors find no profitable mispricing opportunities for any of the four commodities and thus they do not reject the EMH. However, the results indicate the daily opening price provides the most important predicting variable in forecasting price for each commodity and that canola and soybean oil futures prices experience variable seasonality while wheat and feed wheat do not. This observation suggests forecasting models for canola and soybeans oil futures prices must include a longer estimation period to account for seasonality.

In summary, Turner, et al. (1992) find that open interest and trading volume information may assist traders in forecasting future price change directions. Borensztein and Reinhart (1994) indicate a forecast model which includes commodity supplies and Eastern European/Soviet output as independent variables outperforms a random walk forecast for longer-term horizons and correctly forecasts major price turning points. Leuthold, et al. (1994) determine that an elite group of frozen pork belly traders who trade in large quantities possess superior forecasting skills. Ntungo and Boyd (1998) test the application of a neural network which yields results (positive returns) similar to an ARIMA model. Hilliard and Reis (1998) find that while including stochastic interest rates in a three-factor convenience yield model will produce a different forecasted futures price than a two-factor model, it will not produce a different forecasted forward price. Finally, Elfakhani, et al. (1999) test whether thin trading creates profit opportunities; they find no profitable mispricing opportunities after trading costs are considered. Note that if a producer possesses the ability to forecast future price change directions for both futures and spot prices, it would allow him to make better pricing decisions for his expected output.

Section 3: Hedging Strategies

Producers wishing to protect themselves from price variability at harvest will participate in futures markets. Vukina (1992) defines the purpose of futures hedging as “a means to minimize possible revenue losses associated with adverse cash price changes.” In other words, futures markets allow producers to shift the price risk to speculators. However, producers participating in futures markets must decide what

proportion of the expected output they should hedge in the market. Peck (1975) recognizes that although year to year futures prices at planting time for some commodities are virtually constant (i.e., potatoes), the planting time quotes for new crop futures for soybeans and corn vary almost as much as cash harvest prices. Peck believes that producers of commodities should consider hedging to eliminate price risk after making the production decision; this assumes the producer has acknowledged year to year price variability when deciding on the mix of crops for the current year. The results of a price hedging strategy for eggs indicate that “hedging all output over the production period appears to be a reasonable method of stabilizing revenues which did not depend on interpreting a price forecast” (Peck 1975).

Rolfo (1980) looks at hedging ratios under price and quantity uncertainty for a cocoa producer. The results (using both a mean-variance framework and a logarithmic utility function) indicate using a hedge ratio well below unity due to production uncertainty. Rolfo indicates this quantity uncertainty may explain the historic lack of interest on the part of U.S. producers to hedge 100% of the expected crop output.

A producer cannot eliminate both price and output uncertainties by any hedging strategy when he can hedge only in the commodity futures market because the land and crop represent a large (undiversified) portion of his wealth during the growing season (Ho 1984). Using a continuous-time investment and consumption model, Ho analyzes the optimal use of futures in the hedging process when both price and output uncertainties exist. He finds that futures trading provides the perfect hedge only when a perfect correlation exists between price and output or when no output uncertainty exists. Also, hedging has only a negligible impact the more distant the harvest and/or the closer the

harvest; that is, hedging only benefits the producer if he hedges during an intermediate period which falls between when the contract becomes available for trade and a time several weeks in advance of harvest. Ho finds the hedging ratio is less than one and falls as the time to harvest increases. Finally, he indicates producers benefit from a financial instrument such as a *commodity output index* to hedge their output risk. The use of an index to hedge output risk and the futures market to hedge price risk provides the producer with an opportunity to minimize both price and output risk.

For certain commodities, producers and traders may fill futures contracts with one of multiple deliverable grades. Kamara and Seigel (1987) show the assumption that the independence of the distribution of spot and futures price changes relative to when the hedge is put into place and the length of the hedge is inappropriate when the contract can be filled with one of several different grades. Kamara and Seigel propose a model to compute a theoretically correct hedge ratio which they then apply to a sample of wheat futures. Their results indicate the model performs better than a simple full hedge of expected quantities; however, they do not provide a comparison between the results of their model and a simple regression hedge.

Gardner (1989) evaluates the effectiveness of rollover (between years) hedging for locking in a price. His results indicate that 3-year rollover hedges yield lower prices than what the producer can obtain by locking in prices annually for the period from 1972 - 1987. However, he does not consider price levels before locking in hedging strategies.

A key question regarding the EMH relates to whether any one trader can produce greater positive returns than returns generated by other traders due to an ability to correctly predict price movements; Vukina (1992) tests whether traders can use price

forecasts to prepare/implement a hedging strategy to increase profits from hedging.¹⁹ The results of three hedging strategies indicate hedging the entire inventory (routine hedging) outperforms a no hedge strategy while selective hedging (using one of three different selective hedging models (two multivariate models – a cash + futures model and a cash + basis model; and a scalar model based on futures only) outperforms routine hedging. A review of the selective hedging models indicates the multivariate models perform equally and they generate higher profits than the scalar model.

Viswanath and Chatterjee (1992) extend the work of Kamara and Siegel (1987) and compare results obtained from hedging based on Kamara and Siegel's model to results obtained from hedging based on a simple regression hedge for soft and hard wheat. The test results indicate two different simple regression hedging models perform as well as, or better than, the Kamara and Siegel model. Viswanath and Chatterjee (1992) also note the difficulty of extending the Kamara and Siegel model when more than two deliverable grades exist, while no such difficulty exists for the simple regression hedge model.

According to Viswanath (1993), problems with using the traditional regression method to calculate the hedge ratio estimate (a ratio of the unconditional covariance between spot and future price changes and the unconditional variance of futures price changes) include the failure to adjust for convergence of spot and futures prices at maturity and the need to use conditional variance and covariance. Viswanath presents a basis corrected estimation method that addresses both issues; he also uses the method to

¹⁹The analysis makes no attempt to determine the optimal hedging ratio in either a single period or intertemporal time frame. Also, the analysis ignores storage and handling costs, opportunity costs of capital, and cash flow problems.

construct zero-value hedges that reduce the time variation in hedged portfolio returns. A comparison of the (financial) results of hedge ratios based on the traditional and a corrected method reveals the corrected method produces smaller portfolio return variances in many cases; however, corn hedges produce no improvement while wheat and soybean hedges yield only a weak improvement over the traditional method.

In one study, Shafer (1993) addresses the meaning/use of hedge ratios derived from a simple regression of end-of-hedge cash and futures prices and of price changes occurring during the hedge period. Shafer notes: 1) hedge ratios presented in many previous studies reflect systematic basis behavior; and 2) hedge ratios obtained from regressing price levels or price changes aids in forecasting the net price expected from a short or long hedge, but it does not forecast the direction of the price change, the closing basis, or the change in basis. He concludes that when reliable basis change models exist, merchants and other handlers of commodities should engage in discretionary hedging.

Pirrong, et al. (1994) investigate whether delivery point options affect the price of CBOT's corn and soybean futures contracts and how adding delivery points and adjusting for delivery differentials affects pricing and hedging performance. The results indicate that both corn and soybean prices in eight regions (Chicago, Toledo, St. Louis, Central Illinois, Gulf of Mexico, Minneapolis, Central Iowa, and Kansas City) reflect the value of the existing option to deliver at various locations (Chicago or Toledo, Ohio) and that changes in delivery specification for either the grade or the delivery location markedly affects the value of futures contracts as a risk management tool. The addition of a St. Louis delivery point leads to a diversification effect which improves the hedge

results; the fact that St. Louis is a high correlation location enhances the hedge results even further.

The CBOT began trading crop yield insurance futures contracts in 1995; these contracts provide a hedge for crop yield risk. Vukina, et al. (1996) derive optimal hedges in both the price and yield futures markets. Their comparison of hedging effectiveness (a price hedge only, a yield hedge only, both price and yield hedges) shows a firm can reduce its profit variance by hedging with both instruments. The results also indicate that the ability of a dual hedge to reduce profit variance relates to the volatility of the yield contract; the greater the underlying yield variance, the less likely a dual hedge will reduce profit variance as compared to a price hedge only. Finally, test results indicate the effectiveness of the yield hedge depends greatly on the price and yield bases.

A minimum-variance hedge ratio estimation model for storable commodities should include only information available at the time of placing a hedge and the information set should include the current basis according to Lence, et al. (1996). This type of model allows one to determine whether expected storage profitability affects the size of the hedge ratio. Empirical results based on corn and soybean data support the hypothesis that the expected profitability of commodity storage influences actual hedge ratio estimates. Additionally, the results indicate the desired hedge ratios decrease as the expected profitability of storage increases.

Kenyon and Beckman (1997) find that selective 3-year pricing of corn and soybeans could improve the overall price received for producers willing to accept more risk. The strategy yielding the highest prices for corn involves pricing the first year production with cash contracts and using futures contracts for the subsequent two years;

the strategy requires pricing the commodities when December futures prices reach the top 5% of the historical futures price distribution. The soybean strategy requires selling three years of production when November futures prices exceed the top 10-15% of the historical futures price distribution. The producer must use put options with strike prices closest to current futures prices. Overall, these three-year strategies increase the average price of corn by \$0.47 per bushel and of soybeans by \$1.00 per bushel above harvest cash prices; it yields \$0.37 per bushel for corn and \$0.83 per bushel for soybeans over routine annual pricing on April 15 each year.

According to Lien (2000), when the production and futures hedging framework includes Knightian uncertainty,²⁰ inertia exists in hedging behavior. This inertia typically exhibits itself not in the decision frame of “hedge or not hedge” but whether to engage in a full hedge or not. Lien shows that a region for the current futures price exists within which a full hedge provides the optimal hedge for forward contracting. Inertia in the regression hedge ratio becomes more widespread when the producer’s ambiguity increases or when the spot and/or futures price volatility increases.

The authors of one study propose an optimal hedge ratio model which includes yield risk, price variability, basis risk, taxes, and financial (bankruptcy) risk as independent variables (Arias, et al. 2000). Arias, et al. indicate that producers hedge when hedging costs less than the benefits that come from reducing tax liabilities, liquidity costs, or bankruptcy costs. They find that optimal hedge ratios are very fragile depending on the cost of hedging and that adding costs for a producer’s time or his dislike of futures

²⁰ Allows ambiguity in the probability density function of the unknowns including acreage, yield per acre, etc.

could drive the hedge ratio to zero. Arias, et al. also state that “futures exchanges should favor progressive tax rates because they lead to more hedging.” However, when the producer has a net operating loss, the tax-loss carryback can eliminate the need for hedging just as income averaging reduces the producer’s desire to hedge.

Lence and Hayenga (2001) evaluate whether hedge-to-arrive (HTA)²¹ contracts can, theoretically, lock-in high current prices for crops which will be harvested one or more years in the future using 107 years of data. Lence and Hayenga also argue that standard price theory implies that the goal of locking-in higher prices with HTAs is not realistic and that if HTAs had not collapsed in 1996 due to other economic pressures, they would have in the future anyway. The regression results show that a “high proportion of an unusually high nearby futures price would be lost in a rollover . . .” thus providing support for the standard price theory.

Foster and Whiteman (2002) use Bayesian hedge ratios, a naive hedge ratio and a certainty equivalent hedge ratio to calculate hedge ratios for a hypothetical Iowa farmer who wants to hedge his soybean harvest using Chicago futures contracts. They find that a Bayesian-based hedging program and the naive procedure provide similar results for simple situations; however, when more complex specifications are used, the Bayesian approach results in hedging a higher percentage (i.e., 89%) than the naive approach for hedging horizons not exceeding six weeks. Foster and Whiteman indicate that the Bayesian hedge ratio declines as the horizon increases.

²¹Hedge to arrive contracts discussed in this article refer to contracts involving the rolling over of a hedge from a nearby futures contract to more distant futures contracts to solve the problem of missing or thinly traded long-term futures contracts. Some contracts *explicitly* extended two to six crop years into the future (Lence and Hayenga 2001).

In a comparison of the hedging performance of the constant-correlation GARCH hedge model to an ordinary least squares (OLS) model, Lien, et al. (2002) use out-of-sample optimal hedge ratio forecasts to evaluate each model's performance. Their test results indicate that the simpler OLS model outperforms the more complex GARCH model in commodity, currency, and stock index futures markets.

To summarize, Peck (1975) indicates (egg) producers may reduce price risk by hedging once the production decision has been made. However, Rolfo (1980) finds the hedge ratio for a cocoa producer is well below unity. Both Ho (1984) and Vukina, et al. (1996) indicate producers can reduce total profit variance by hedging price risk with futures contracts and yield risk with either an output index (Ho) or a crop yield insurance futures contract (Vukina, et al.).

Kamara and Siegel (1987) propose modifying the simple regression hedge model to include the fact that some futures contracts will accept one of multiple delivery grades of the commodity; however, Viswanath and Chatterjee (1992) find the simple hedge model performs better than the more complicated Kamara and Siegel model. Viswanath (1993) compares the traditional regression hedge model to a basis corrected estimation hedge model and determines the basis corrected model provides no significant improvement over the simple regression model. Similarly, Lien, et al. (2002), find that a simpler OLS hedging model outperforms a more complex GARCH model. Although Gardner (1989) finds that an annual hedge strategy produces higher prices than a three-year rollover strategy, Kenyon and Beckman (1997) indicate a three-year pricing strategy for soybeans and corn could increase the overall price received for producers willing to accept more risk. Foster and Whiteman (2002) indicate that Bayesian hedge ratio models

outperform naive models in more complex situations and that the hedge ratio declines as the time to contract maturity lengthens.

Vukina (1992) states that traders engaging in routine hedging of the entire expected inventory would produce higher profits than those employing a no hedge strategy; selective hedging would provide an even higher return. Shafer (1993) agrees that interested parties should hedge when reliable basis change models exist. According to Pirrong, et al. (1994), the addition of a St. Louis delivery point for futures contracts enhances the hedging results for both corn and soybeans; an increase in the futures price reflects the value of the St. Louis delivery point. Lence, et al. (1996) note that hedge models should include only information available when the hedge must be placed. Lien (2000) shows that inertia in the regression hedge ratio becomes more widespread when the producer's ambiguity increases or when the spot and/or futures price volatility increases. Arias, et al (2000) indicate producers hedge when hedging costs less than the benefits that come from reducing tax liabilities, liquidity costs, or bankruptcy costs; they also find that optimal hedge ratios are very fragile depending on the cost of hedging. Finally, Lence and Hayenga (2001) indicate that HTA contracts do not generally succeed in locking-in current high prices for crops that will be harvested one or more years in the future. In an extension of previous hedge research, this dissertation attempts to determine whether a hedge ratio exists that minimizes price risk for expected corn and soybean yields.

Section 4: Conclusions

Several premises underlying this dissertation are drawn from the literature and summarized in this section. First, prior results indicate crop subsidies are incorporated into land values. Subsidies affect non-land owning producers in three ways: the rent they must pay, the subsidy they receive after complying with all government regulations, and the market price they receive for their yield. Subsidies affect land-owning producers in a similar manner; the only difference is that it affects the value of the land they own instead of the rent they pay. While emergency assistance bills passed by Congress since FAIR appear to be aimed at subsidizing producers for low market prices, producers cannot depend on Congress to continue to provide this type of assistance. Therefore, both types of producers must find and implement other mechanisms to stabilize income.

Second, many studies question the government's role (i.e., crop subsidies) in stabilizing commodity prices and indicate that, at best, government intervention may reduce commodity price volatility. Because of the government's failure to effectively stabilize commodity prices, the individual producer is faced with developing an income stabilization program. Futures contracts provide one such mechanism to the producer.

Third, previous research has generally yielded mixed results regarding the efficiency of commodity futures markets. Overall, general tests of commodity market efficiency support the EMH. Other research finds seasonal and other anomalies including a Monday effect and a time to maturity effect. Results from cointegration tests vary between no correlation, cointegration only between related commodities, widespread co-movement in agricultural commodity prices, cointegration of cash and futures market for

specific commodities, etc. Previous research regarding the presence of risk premia in commodity prices (i.e., backwardation, etc.) and studies focusing on the use of pricing models also yield mixed results. Some authors conclude that futures prices provide unbiased estimates of future spot prices but others do not; the authors of one study reject the ICAPM for commodity futures contracts while the authors of another study accept the ICAPM; and, the results from another study suggest that portfolios containing futures do not lie on the same estimated SML as asset portfolios. Price forecasting research indicates open interest, trading volume, commodity supply, Eastern European/Soviet output, and stochastic interest rate information may assist in forecasting price changes. Finally, prior research finds that thin trading does not create profitable mispricing opportunities after considering trading costs. This dissertation extends the previous research by determining if the daily corn (soybean) futures price consistently provides a higher/lower price than the related daily cash spot price, after adjusting for an arbitrage bound.

Fourth, some hedging research results indicate cross year hedging provides higher prices. In contrast, some results indicate that annual hedging will result in higher prices. Although the exact hedge ratio of the expected yield and the form of the regression model (simple, basis correction, etc.) used to generate the hedge ratio has been debated, a number of studies suggest a simple model outperforms more complicated models. Other studies indicate producers could reduce total profit variance by hedging price risk with futures contracts and yield risk with some type of yield futures contract. Thus, previous hedging studies have reached no consensus on a “preferred” hedge ratio model. Accordingly, this dissertation will extend the hedging literature by determining if a

calculated hedge ratio of expected output will yield better (financial) results than a 100% hedge for producers.

CHAPTER THREE

METHODOLOGY

This dissertation attempts to answer two related questions. First, will daily corn (soybean) futures prices consistently yield higher/lower than the related daily cash spot price, after adjusting for an arbitrage bound? Second, does a hedge ratio exist that minimizes price risk for corn (soybean) producers? See Chapter One (Section 8) for definitions of hedging and hedge ratios.

Section 1 of this chapter contains information concerning the hypothesis addressing whether daily corn (soybean) futures prices are consistently higher/lower than the related daily cash spot price, after adjusting for an arbitrage bound. Corn and soybeans are used in this dissertation because they have the largest futures trading volume and the highest production volume of all agricultural commodities. Section 2 includes information about the hypothesis relating to the calculations of hedge ratios for these commodities. Finally, Section 3 presents a contingency table model (Table 3.1) used to test the hypothesis discussed in Section 1 regarding the daily futures versus cash spot prices and a summary table (Table 3.2). It also includes the mean-variance framework and the logarithmic function which will be used to calculate the hedge ratios presented in Section 2.

**Section 1: Hypothesis Related to the Value
of Cash Spot Prices vs. Futures
Contract Prices**

For futures prices to consistently provide higher/lower prices than daily cash spot prices, after considering the arbitrage bound proposed by Kolb (1999), some level of inefficiency must exist in the commodity market. While results from most studies generally support the weak form EMH and some results support the semi-strong form, Johnson, et al. (1991), DeCoster, et al. (1992), Gay, et al. (1994), Dorfman (1993), Bessembinder, et al. (1995), and Irwin, et al. (1996) indicate some level of inefficiency may exist in the commodity futures market. Also, Milonas (1991) finds a fourth seasonality, the “half-month effect,” in addition to a month, year, and maturity effect for corn/wheat/soybeans (seasonal commodities) and soy meal/soy oil (non-seasonal ones).

If commodity futures prices include a risk premium, futures prices should consistently yield higher prices than cash spot prices, after adjusting for an arbitrage bound; this creates the question of whether a particular day (or days) within the life of a futures contract provides the most variance between daily futures and cash spot prices. Telser (1958) rejects backwardation while studies by others, Bodie and Rosansky (1980), Chang (1985), Fama and French (1987), Kolb (1992), and Beck (1993) support backwardation for certain commodities. Studies focusing on pricing models also provide mixed results. While Dusak (1973) and Fama and French (1987) conclude futures prices provide some forecast power of future spot prices, Kenyon, et al. (1993) and Zulauf, et al. (1999) indicate futures prices are not good indicators of future spot prices for corn or soybeans. These results generate the question, “If futures contract prices are not good

indicators of future spot prices, does that increase or decrease a producer's willingness to hedge expected output?"

Cointegration studies by Malliaris and Urrutia (1996), Chaudhry and Christie-David (1998), and Chow (1998) find cointegration between grain and soy complex prices, within the grain and oil seeds group, between this group and other agricultural product groups, and between spot and futures markets. Studies by Fortenbery and Zapata (1993), Hudson, et al. (1996), and Kellard, et al. (1999) focusing on the consistent cointegration of cash and futures markets for specific commodities provide mixed results. Finally, Malliaris and Urrutia (1996) indicate the price discovery function of one commodity futures contract also provides relevant information for other related commodity futures contracts; soybeans and corn are both used as feed grains. If Malliaris and Urrutia are correct, when daily corn futures contracts consistently provide higher/lower prices than daily cash spot prices, the same should be true for soybean futures prices. Likewise, when daily corn futures contracts do not consistently provide higher/lower prices than daily cash spot prices, the same should be true for soybean futures prices.

Each of these market functions (i.e., inefficiency, risk premiums, etc.) provide an opportunity for producers to receive higher prices for their output by purchasing futures contracts instead of accepting cash spot prices at harvest. This dissertation extends the literature related to basic price timing issues by comparing daily futures contract prices to same day cash spot prices to determine whether futures prices provide consistently higher/lower prices than cash spot prices, after adjusting for an arbitrage bound. The Timing Model, presented at the beginning of Section 3 of this chapter, is used to test the following null hypothesis relating to price timing.

Hypothesis 1:

A time frame does not exist in which daily corn (soybean) futures prices are consistently higher/lower than the related daily cash spot prices, after adjusting for an arbitrage bound.

Hypothesis 1 is subdivided into two farm geographic regions (south and midwest) and tested individually for each geographic region. Corn (soybean) futures contracts for September (November) relate to southern producers while December (January) contracts relate to midwestern producers. Additionally, the hypothesis will also be subdivided by groups of years where March inventory levels and March projected yields fall into specified ranges (low, medium, and high) to determine the predictability of bound violations based on these items. As discussed in Chapter One (Section 3), the March inventory stock level is the last one published before both southern and midwestern producers must make their final production decisions. This corresponds with Borensztein and Reinhart's (1994) findings that a revised price forecast model which includes beginning commodity supplies outperforms models which do not include this variable.

Section 2: Hypothesis Related to the Hedge Ratio Percentage

Historically, producers of all types of commodities have tended to hedge less than 100% (unity) of their expected output (Rolfo 1980) and previous research yields mixed results regarding the percentage of expected output that a producer should hedge. Rolfo (1980) recommends hedging less than unity, while Vukina (1992) favors full hedging over no hedging and selective hedging over full hedging. Disagreement also exists regarding

whether simple or complex regression models provide better hedge results. Kamara and Siegel (1987) propose a complex regression hedge model; however, Viswanath and Chatterjee (1992) and Viswanath (1993) find that simple hedge models perform better than more complicated models. While Gardner's (1989) results support hedging annually, Kenyon and Beckman (1997) favor a three-year pricing strategy for corn and soybeans. Shafer (1993) notes that interested parties should hedge when reliable basis change models exist. Lence, et al. (1996) indicate that any hedge models used should include only information available when the hedge must be placed. Lien (2000) shows that inertia in the regression hedge ratio becomes more widespread when the producer's ambiguity increases or when the spot and/or futures price volatility increases. Finally, Arias, et al. (2000) indicate producers hedge when hedging costs less than the benefits that come from reducing tax liabilities, liquidity costs, or bankruptcy costs.

To extend previous hedge research, this dissertation attempts to determine whether a hedge ratio exists that minimizes producer price risk for corn and soybeans based on Rolfo's (1980) mean-variance and logarithmic utility functions. Due to yield uncertainty resulting from weather variability (including the impact on planting time), irrigation ability (including current year local restrictions on water usage), seed quality, pest problems, etc., the hedge ratio is expected to be less than 100% of the anticipated yield. Peck (1975) believes that commodity producers should consider hedging to eliminate price risk after making the production decision; if producers make production decisions based on current futures prices for harvest month contracts, this advice seems particularly relevant. The Hedge Ratio Models, included in Section 3 of this chapter are used to test the following null hypothesis.

Hypothesis 2:

A partial hedge will not consistently allow a producer to receive a higher average price than a full hedge of expected corn (soybean) yield.

Similar to Hypothesis 1, Hypothesis 2 is subdivided into two farm regions (south and midwest). Corn (soybean) futures contracts for September (November) relate to southern producers while December (January) contracts relate to midwestern producers.

Section 3: Models Used to Evaluate Hypotheses

Subsection 3.1: Timing Model

Cumby and Modest (1987) based the Timing Model they used in evaluating ten forecasting services (firms) ability to correctly predict the direction of movements in bilateral exchange rates on a test first proposed by Henriksson and Merton (1981). As Cumby and Modest acknowledge, the Henriksson and Merton test allows for independence between the probability of a correct forecast and the magnitude of the realized return/loss on the investment. Unlike Cumby and Modest's analysis of a firm's forecast ability, this dissertation will determine whether any time frame exists in which futures contract prices consistently yield higher/lower prices compared to daily cash spot prices, after adjusting for Kolb's (1999) arbitrage bound.

The basic timing model simply involves comparing daily cash spot prices to the daily futures contract prices for 232 trading days (per year for thirty-one years) prior to the contract expiration and determining whether the futures price is higher, lower, or equivalent to the daily cash spot price. However, note that the daily cash spot price is

adjusted using Kolb's (1999) arbitrage bound, so that one would actually compare a daily futures price to a daily cash spot price "range."

During the contract expiration month, the number of days the contract trades varies by year and by contract month. For example, one year the September corn contract may trade until September 12 and another year it may trade until September 18. To promote consistent analysis, trade day 1 is defined as the last trade day of the month before the contract expiration month (e.g., August 31 for a September corn contract when August 31 falls on a weekday).

The arbitrage adjustment to the Timing Model includes an interest rate and transaction cost component. The adjustment requires using separate interest rates for lenders and producers; both of these interest rates are taken from the Interest Rates and Bond Yields table (typically page 30) in the monthly report called *Economic Indicators/prepared for the Joint Committee on the Economic Report by the Council of Economic Advisors*. To test the sensitivity of the results to changes in the interest rate, the analysis will be performed using annual interest rates as well as interest rates adjusted for the time remaining to contract maturity.

The transaction cost component (.1%) is based on the average transaction cost for a producer as quoted by the following companies: efutures.com, Farmer's Grain, Infinity Brokerage Services, ORION Futures Group, Salomon Smith Barney, and Transitions Trading. To test the sensitivity of the results to changes in the transaction cost, the analysis will also be performed using transaction costs of 2% and 4%.

The remaining data for this dissertation consist of daily cash prices and daily futures contract prices for contracts maturing at harvest for the 1970 - 2000 crop years

(i.e., a 31-year period). Acreage and yield information used in the hedge ratio calculation is taken from the NASS/USDA's *Track Records - United States Crop Production*.

The Timing Model, including the arbitrage bound adjustment, follows.

$$S_0 (1-T) (1+C_L) \leq F_0 \leq S_0 (1+T) (1+C_B)$$

where,

S_0 = daily cash settlement price

F_0 = daily futures price

T = transactions cost (on a percentage basis)

C_L = lender's interest rate

C_B = borrower's interest rate (i.e., producer's rate)

TABLE 3.1
Detail of Actual Results

	Above Violations	Below Violations	
Day	$R^*(t) \geq R(t)$	$R^*(t) < R(t)$	No Violations
232	n_{2322}	n_{2321}	n_{2320}
...
1	n_{0012}	n_{0011}	n_{0010}
Totals	N_2	N_1	N_0

where,

Day 232 = the day the futures contract is traded that is exactly 232 trading days before the 1st day of the month in which the futures contract will mature.

- t = the specific trading day (runs from trading Day 232 to Day 1).
- $R^*(t)$ = the futures contract price on the indicated day.
- $R(t)$ = the daily cash spot price, adjusted for an arbitrage bound, available for the applicable commodity.
- N_0 = the total number of outcomes where the daily futures price falls within the lower and upper arbitrage bounds surrounding the daily cash spot price.
- N_1 = the total number of outcomes where the daily futures price exceeds the upper (arbitrage) bound on the daily cash spot price.
- N_2 = the total number of outcomes where the daily futures price is less than the lower (arbitrage) bound on the daily cash spot price.
- n_{0010} = the number of years in which the daily futures contract price falls within the lower and upper arbitrage bounds surrounding the daily cash spot price.
- n_{0011} = the number of years in which the daily futures contract price exceeds the upper (arbitrage) bound on the daily cash spot price.
- n_{0012} = the number of years in which the daily futures contract price is less than the lower (arbitrage) bound on the daily cash spot price.

The comparison of the daily cash spot price, after adjusting for an arbitrage bound, and the daily futures contract price for each trade day for each year can then be tabulated

by trade day. Table 3.1 is an example of how the detailed comparisons were accumulated by trade day for each contract year tested.

Daily futures contract prices and daily cash prices, adjusted for an arbitrage bound, will be compared for September/December corn contracts and November/ January soybean contracts. Due to the volume of data, the detailed comparison results by day, as described above, will not be presented. Instead, Table 3.2 will be used to present the number of trading days for all years tested in which the futures contract price differs or equals the daily cash spot price, after adjusting for an arbitrage bound.

The “Above Violations” column represents those trade days in which the daily futures price exceeds the upper arbitrage bound surrounding the daily cash spot price. The “Below Violations” column represents those trade days in which the daily futures price falls below the lower arbitrage bound surrounding the daily cash spot price. The “No Violations” column represents those trade days in which the daily futures price falls between the upper and lower arbitrage bounds surrounding the daily cash spot price.

Subsection 3.2: Hedge Ratio Models

To determine the hedge ratio for a cocoa producer subject to both price and quantity uncertainties, Rolfo (1980) developed models using both a mean-variance framework and a logarithmic utility function. (Both models are presented at the end of this subsection.) The mean-variance framework assumes both price and yield are

TABLE 3.2
Summary of Results by Day

	Violations				No Violations		Total	
	Above		Below					
	#	%	#	%	#	%	#	%
Corn September December								
Soybeans November January								

unknown with all uncertainty resolved at harvest. Rolfo stated that the “optimal hedge n^* is a solution of the first-order condition $dEU/dn = 0$: $n^* = \text{cov}(p_Q, p_f)/\text{var}(p_f) + (f - E(p_f))/2m(\text{var}(p_f))$.” The mean-variance framework also assumes that the producer either has a risk aversion that increases with wealth or has a constant absolute risk aversion. Rolfo (1980) calls both of these assumptions unrealistic.

In contrast, the logarithmic function allows for decreasing absolute risk aversion and constant relative risk aversion and thus is not subject to Rolfo’s concerns about the unrealistic limitations of the mean variance model. Rolfo stated that this function implies an optimal holding of futures contracts n^*_i defined as: $E[(p_f - f)/(p_Q + n^*_i(f - p_f))] = 0$. He measured the quantity forecast error $e^Q_i(t)$ as: $e^Q_i(t) = [Q_i(t) - Q_i^c(t)]/Q_i(t)$. After replacing p , p_f , and Q by $f(1 + e^p)$, $f(1 + e^p_f)$, and $Q_i^c(1 + e^Q_i)$, respectively, one can then approximate both the mean-variance and the logarithmic functions found below. This dissertation extends Rolfo’s use of both models to calculate hedge ratios for corn and soybeans.

Variables for both the Mean-Variance framework and the Logarithmic Function are defined after the presentation of both models.

Mean-Variance Framework

$$\frac{n_i^*}{Q_i^e} = \frac{\text{cov} [(1 + e^p) (1 + e_i^Q), e_f^p]}{\text{var} (e_f^p)} - \frac{E(e_f^p)}{2mf Q_i^e \text{var} (e_f^p)}$$

Logarithmic (Bernoulli) Utility Function

$$\sum_{t=1}^X e^p(t) / ([1 + e^p(t)][1 + e_i^Q(t)] - e^p(t)n_i^*/Q_i^e) = 0$$

Variable Definitions for Both Hedge Models

n^* = the amount of the expected crop yield which should be hedged.

$p_0(t)$ = the price forecast as of the first day of the month six months before the contract matures (e.g., June 1 for a December contract).

$p(t)$ = the cash price on the 14th (or Monday if on a weekend) of the contract month.

$p_f(t)$ = the futures contract price as of the first day of the month in which the contract matures.

t = the specific year being analyzed.

Q_i^e = the output forecast.

$Q_i(t)$ = the actual output.

$e^p(t)$ = $[p(t) - p_0(t)]/p_0(t)$

$e_f^p(t)$ = $[p_f(t) - p_0(t)]/p_0(t)$

$e_i^q(t)$ = $[Q_i(t) - Q_i^e(t)]/Q_i(t)$

f = the futures price quoted before harvest.

m = the measure of risk aversion; has a dimension of $(pQ)^{-1}$

Section 4: Conclusions

This dissertation extends the literature related to basic price timing issues by comparing daily futures contract prices to daily cash spot prices, after adjusting for an arbitrage bound, to determine whether daily futures prices provide consistently higher/lower prices than daily cash spot prices. If futures prices are consistently different from daily cash spot prices, it indicates some inefficiency may exist in the corn and soybean commodity futures markets.

Additionally, this dissertation extends the literature by computing hedge ratios for corn and soybeans using Rolfo's (1980) mean-variance and logarithmic utility functions. Due to yield uncertainty, the hedge ratios are expected to be less than 100% of the anticipated yield.

CHAPTER FOUR

DATA AND EMPIRICAL FINDINGS

Chapter 4 has three sections. Section 1 details the procedures used in aligning the futures contract data while Section 2 includes the results from the Timing Model. Section 3 contains the hedge ratio calculations and the implications of those hedge ratios for producers. Finally, Section 4 provides the conclusions drawn from the results of the application of the Timing Model and the hedge ratio calculations.

Section 1: Data Collection

The daily cash settlement and daily futures contract prices (for the years 1970 through 2000) were purchased from the FII.²² Since the raw data list included holidays and weekends, the data had to be aligned; that is, non-trade days were removed from each year of data for both the daily cash settlement and daily futures contract prices. As previously discussed, this dissertation defines Day 1 as the last trading day of the month before the contract expires. Therefore, Day 1 for a September 2000 corn futures contract would be Thursday, August 31, 2000 while Day 1 for a September 1997 contract corresponds to Friday, August 29, 1997. As indicated in Chapter 3 (Section 3, Subsection

²²As of April 2003, the FII (Futures Industry Institute) no longer sells this data.

2 - Hedge Ratio Models), the interest rate data was taken from the Interest Rates and Bond Yields table in the *Economic Indicators/prepared for the Joint Committee on the Economic Report by the Council of Economic Advisors*. The transaction costs were calculated based on the costs quoted by efutures.com, Farmer's Grain, Infinity Brokerage Services, ORION Futures Group, Salomon Smith Barney, and Transitions Trading. Finally, the beginning stock data was obtained from the annual *Track Records United States Crop Production* report published by the NASS/USDA.

Section 2: Timing Model Results

The results of the Timing Model, after adjusting for an arbitrage bound, are displayed in summary format in Table 4.1 below. Remember that if the futures price falls within the calculated lower and upper bounds, then it is reported on the table as a "No Violation" year. In turn, if the futures price is below the lower bound limit, it is reported in the table as a "Below Violation." Finally, if the futures price exceeds the upper bound limit, it is included in the table as an "Above Violation."

As shown in Table 4.1, a significant number of days occurred in which the daily futures price did not fall within the daily cash spot price arbitrage bound. On the average, 16% of the daily futures prices had "Above Violations" across the two corn and two soybean contracts, 72% had "Below Violations," and 12% had "No Violations." In summary, the results do not support the null hypothesis which stated that "a time frame does not exist in which daily corn (soybean) futures prices are consistently higher/lower than the related daily cash spot prices, after adjusting for an arbitrage bound."

TABLE 4.1
Summary of Results by Day

	Violations				No Violations		Total	
	Above		Below					
	#	%	#	%	#	%	#	%
Corn								
September	1,915	26.6	4,523	62.9	754	10.5	7,192	100.0
December	1,657	23.0	4,869	67.7	666	9.3	7,192	100.0
Soybeans								
November	370	5.1	5,752	80.0	1,070	14.9	7,192	100.0
January	580	8.1	5,580	77.6	1,032	14.3	7,192	100.0
Total	4,522	15.7	20,724	72.1	3,522	12.2	28,768	100.0

Several unusual items were noted when reviewing the detailed results. First, for September corn contracts, nine trade days (falling between trade days 42 and 51) had no year that fell in the “No Violation” category. For each of those nine trading days, six years were “Above Violations” while twenty-five years were “Below Violations.”

Second, for December corn contracts, five trade days (2, 97, 100, 101, and 164) had no year that fell in the “No Violation” category. On trade day 2, all thirty-one years had “Below Violations.” On trade day 97, six years had “Above Violations” and twenty-five years had “Below Violations.” Trade days 100 and 101 had seven years with “Above Violations” and twenty-four years with “Below Violations.” Finally, on trade day 164, eight years had “Above Violations” and twenty-three years had “Below Violations.”

Third, for November soybean contracts, four trade days (56, 77, 84, 86) had no year that fell in the “No Violations” category. Trade days 56, 84, and 86 had one year of

“Above Violations” and thirty years of “Below Violations.” Trade day 77 had “Below Violations” for all thirty-one years.

Finally, for January soybean contracts, twenty-three trade days (days 1 - 21, 34, and 35) had no year that fell in the “No Violations” category. For each of these twenty-three trading days, all thirty-one years had “Below Violations.”

A comparison of the March 1 grain stock levels across the thirty-one years was performed to determine the propensity of the futures contracts to fall within, below or above the arbitrage bound. The results of the comparison suggest no evidence that a relationship exists between where the futures price falls and the March 1 grain stock level for any contract.

Subsection 2.1: Sensitivity Analysis

Tables 4.2 through 4.4 present the results of the sensitivity analysis with respect to changes in interest rates and transaction costs. The results presented in Table 4.1 are based on using annual interest rates (even though the time to maturity is less than one year for each trade day) and transaction costs of .1% (which is based on the current average transaction cost previously discussed) to calculate the bound limits. In contrast, Table 4.2 presents results using an interest rate adjusted for the time remaining to contract maturity (e.g., for day 232 multiply the published annual interest rate by 11/12).

Adjusting the interest rates used in the bound limit calculations to reflect the interest cost for the period from the trade date to the contract maturity simply shifts the bound limits; accordingly, the results also shift slightly. Specifically, the number of “Above Violations” increases while “Below Violations” and “No Violations” decrease.

TABLE 4.2
Summary of Results by Day
Adjusted Interest Rates

	Violations				No Violations		Total	
	Above		Below					
	#	%	#	%	#	%	#	%
Corn								
September	3,417	47.5	3,228	44.9	547	7.6	7,192	100.0
December	3,392	47.2	3,388	47.1	412	5.7	7,192	100.0
Soybeans								
November	2,749	38.2	3,846	53.5	597	8.3	7,192	100.0
January	3,557	49.5	2,949	41.0	686	9.5	7,192	100.0
Total	13,115	45.6	13,411	46.6	2,242	7.8	28,768	100.0

Similar to the results presented in Table 4.1, a significant number of days occur in which the daily futures price does not fall within the cash spot price arbitrage bound. In fact, using an adjusted interest rate increased the number of “Above Violations” from 16% to 46%, decreased the number of “Below Violations” from 72% to 47% and decreased the number of “No Violations” from 12% to 8%.

Several unusual items were again noted when reviewing the detailed results. First, the results from the adjusted interest rate model indicate that September corn contracts had twenty trade days (days 3, 5, 8-11, 16-23, 31, 32, 39, 69, 70, and 103) in which the futures price was never categorized as “No Violation.” The number of violations was approximately evenly split between “Above Violations” and “Below Violations.”

Second, for December corn contracts, 43 trade days (6-10, 12-25, 32, 35, 38, 39, 41, 42, 44, 59-63, 73, 85, 87, 88, 106, 116, 117, 152, 156, 176, and 177) had no year

which fell in the “No Violations” category. Trade days 6-10, 12-17, 32, 35, 38, 39, 41, 42 and 44 had “Above Violations” from twenty-five to thirty years and “Below Violations” from one to six years. All thirty-one years had “Above Violations” on trade days 18-25. Trade days 59-63, 73, 85, 87, 88, 106, 116, 117, 152, 156, 176, and 177 had violations that were almost evenly split between “Above Violations” and “Below Violations.”

Third, November soybean contracts had twenty-three trade days (1, 3-5, 9, 10, 13-22, 34, 36-38, 96, 166, and 174) in which no year fell in the “No Violations” category. On trade days 13 and 15-21, all thirty-one years had “Above Violations” for the November contracts, while trade days 3, 9, 10, 14 and 22 had thirty years of “Above Violations” and one year of “Below Violations.” Trade days 4 and 5 had twenty-nine years with “Above Violations” and two years with “Below Violations.” Trade day 1 had twenty-eight years with “Above Violations” and three years with “Below Violations.” Trade days 34 and 36-38 had violations that were approximately evenly split between “Above Violations” and “Below Violations.” Trade day 96 had nine years with “Above Violations” and twenty-two years with “Below Violations.” Finally, on trade days 166 and 174, there were twelve years with “Above Violations” and nineteen years with “Above Violations.”

Finally, January soybean contracts had eighteen trade days (12, 14, 50-56, 58, 59, 63-65, 68, 82, 128, and 132) in which the futures price was never categorized as “No Violation.” Trade days 12, 14, 50, 63-65 and 68 had “Above Violations” from twenty-four to twenty-nine years and “Below Violations” from two to seven years. Trade days 51-56, 58, and 59 had thirty years with “Above Violations” and one year with “Below

Violations.” Additionally, trade days 82, 128, and 132 had bound violations that were approximately evenly split between “Above Violations” and “Below Violations.”

In addition to testing the sensitivity of the timing model to time-adjusted interest rates, one must consider the sensitivity of the analysis to changes in transaction costs. Tables 4.3 and 4.4 present the summary of results using transaction costs of 2% and 4% and annual interest rates (i.e., the interest rates used in Table 4.1).

TABLE 4.3
Summary of Results by Day
2% Transaction Costs

	Violations				No Violations		Total	
	Above		Below					
	#	%	#	%	#	%	#	%
Corn								
September	1,421	19.8	3,830	53.2	1,941	27.0	7,192	100.0
December	1,279	17.8	4,138	57.5	1,775	24.7	7,192	100.0
Soybeans								
November	40	0.6	5,056	70.3	2,096	29.1	7,192	100.0
January	263	3.7	4,590	63.8	2,339	32.5	7,192	100.0
Total	3,003	10.4	17,614	61.2	8,151	28.3	28,768	100.0

TABLE 4.4
Summary of Results by Day
4% Transaction Costs

	Violations				No Violations		Total	
	Above		Below					
	#	%	#	%	#	%	#	%
Corn								
September	996	13.9	3,052	42.4	3,144	43.7	7,192	100.0
December	988	13.7	3,378	47.0	2,826	39.3	7,192	100.0
Soybeans								
November	3	0.0	3,938	54.8	3,251	45.2	7,192	100.0
January	90	1.2	3,233	45.0	3,869	53.8	7,192	100.0
Total	2,077	7.2	13,601	47.3	13,090	45.5	28,768	100.0

The use of a 2% (4%) transaction rate versus a .1% rate increases the number of “No Violations” from 12% to 28% (45%) and it decreases the number of bound violations from 88% to 72% (55%). While the analysis shows that increasing the transaction cost decreases the number of “No Violations,” overall, there are still a significant number of bound violations.

Subsection 2.2: Additional Considerations

The comparisons involved in the timing model were performed using daily settlement prices for both daily cash spot prices and daily futures prices. Given that settlement prices often reflect an average of several prices “discovered” at the end of the trading day, the prices used may not equal an actual trade price. Additionally, using opening prices on the following trade day may result in a very different price as well. The large number of bound violations may not have occurred if intraday or opening futures

and cash spot price data had been used in this dissertation. However, given these limitations regarding the data used, the results do not provide support for the null hypothesis that daily futures prices do not yield significantly higher/lower prices than daily cash spot prices. Primarily, the fact that twenty-three trade days exist (using an unadjusted interest rate) in the January soybean futures contract when the futures price falls below the band for thirty-one straight years provides evidence supporting the ability of a trader or producer to make a profit from purchasing futures contracts after adjusting for interest and transaction costs.

Section 3: Hedge Ratio Model Results

Table 4.5 displays the hedge values calculated using the mean variance hedge formula. Recall that reverse hedging (as defined Chapter 1, Section 8) indicates that producers purchase futures contracts instead of selling them when they wish to hedge against price risk (as compared to the normal practice of selling futures contracts when producing the item). Unlike the Rolfo study in which reverse hedging becomes optimal for values of m less than 0.0001 (calculated using Rolfo's mean-variance model), this dissertation finds that soybean and corn producers should never engage in reverse hedging.

According to Table 4.5, southern producers should hedge 47% of their expected corn crop when using September futures contracts and they should hedge approximately 49% of their expected soybean crop when using November futures contracts. These percentages approximate the expected results of hedging less than 50% of the expected output. In contrast, the results indicate that midwestern producers should hedge only 21%

of their expected corn crop when using November futures contracts and 102% of the expected soybean crop when using January soybean contracts.

Table 4.6 presents the hedge ratios calculated using the logarithmic function. Unlike Rolfo's results in which the logarithmic function indicated that cocoa producers should hedge approximately one-half or less of the amount the mean-variance

TABLE 4.5
Hedge Ratios - Mean Variance Framework

Risk-Aversion Parameter m	Sep Corn	Dec Corn	Nov Soy	Jan Soy
1,000.00000	0.47156	0.20676	0.48917	1.01986
100.00000	0.47156	0.20676	0.48917	1.01986
10.00000	0.47156	0.20676	0.48917	1.01986
1.00000	0.47156	0.20676	0.48917	1.01986
0.10000	0.47156	0.20676	0.48917	1.01986
0.01000	0.47156	0.20676	0.48917	1.01986
0.00100	0.47157	0.20676	0.48916	1.01990
0.00010	0.47167	0.20678	0.48911	1.02028
0.00001	0.47271	0.20697	0.48856	1.02403

TABLE 4.6
Hedge Ratios - Logarithmic Function

	Sep Corn	Dec Corn	Nov Soy	Jan Soy
Hedge Ratio	0.83480	0.40067	0.75919	2.43352

framework indicated, this dissertation found the opposite. For each contract month tested, the logarithmic model results indicate producers should hedge almost double the amount

the mean-variance model suggests. For example, southern producers using the mean-variance model would hedge 47% (49%) of their expected corn (soybean) crop while southern producers using the logarithmic model would hedge 83% (76%) of their expected corn (soybean) crop. Likewise, midwestern producers would hedge 21% (102%) of their expected corn (soybean) crop using the mean-variance model while midwestern producers using the logarithmic model would hedge 40% (243%) of their expected corn (soybean) crop. Hedging 243% involves speculative trading for midwestern producers hedging with January soybean contracts.

The results from the mean-variance framework and the logarithmic utility function do not provide support for the null hypothesis that “a partial hedge will not consistently allow a producer to receive a higher average price than a full hedge of expected corn (soybeans) yield.” In fact, results from both corn contracts and the November soybean contract suggest that producers should hedge less than 100% of their expected output while results from the January soybean contract suggest that producers should hedge more than 100% of their expected output.

The January soybean futures contract results are substantially different from the results of the other three contracts. The suggestion that producers should hedge more than 100% using January soybean contracts may be attributable to the fact that the covariance of the price error forecast with the quantity forecast, and the variance of the price error forecast, were almost equal.

Section 4: Conclusions

Results from this dissertation suggest that the use of commodity futures contracts (i.e., hedging) may reduce price risk. In turn, after deciding to engage in futures hedging, producers must make two related decisions: 1) they must determine when to hedge; and, 2) they must determine how much to hedge.

The results from the Cumby and Modest (1987) Timing Model, do not provide support for the null hypothesis that “. . . daily corn (soybean) futures prices are not consistently higher/lower than the related daily cash spot prices, after adjusting for an arbitrage bound.” In fact, the results indicate that futures prices more often fall “below” the arbitrage lower bound limit than they do within or above the bound when using an unadjusted interest rate model. This dissertation used daily settlement prices for corn and soybean futures and cash prices; different results may have occurred if intraday or opening price data had been used.

This dissertation used Rolfo’s (1980) mean-variance framework and logarithmic function to calculate hedge ratios for corn and soybeans. Although Rolfo found that the mean-variance model yielded a higher hedge ratio than the logarithmic function (the mean-variance ratio is approximately double that of the logarithmic ratio) for cocoa, this dissertation found just the opposite for corn and soybean futures. For corn and soybeans, the logarithmic ratio is approximately double that of the mean-variance ratio for both midwestern and southern producers. The results from both models do not provide support for the null hypothesis that “a partial hedge will not consistently allow a producer to receive a higher average price than a full hedge of expected corn (soybeans) yield.” Results for both corn contracts and the November soybean contract suggest that producers

should hedge less than 100% of expected output while the results from the January soybean contract suggest that producers should hedge more than 100% of their expected output.

CHAPTER FIVE

CONCLUSIONS

The purpose of this chapter is to provide a summary of this dissertation. Specifically, this chapter begins with a summary of the findings and implications of the results. It then concludes with a discussion of the limitations of this dissertation and provides suggestions for future research. A set of tables summarizing the literature review and a list of references follow this chapter.

Section 1: Summary and Implications

This dissertation evaluates the use of futures contracts as a hedge against price risk and is motivated by two key questions. First, will daily corn (soybean) futures prices consistently yield higher/lower prices than daily cash spot prices, after adjusting for an arbitrage bound? Second, does a hedge ratio exist that minimizes price risk for corn (soybean) producers? The remainder of this section provides an overview of data collection, data analysis, and the results of this dissertation.

Data consisted of daily futures prices and daily cash spot prices for the September/December corn futures contracts and the November/January soybean contracts from the Futures Industry Institute. The data include daily futures prices and daily cash

spot prices from 1970 through 2000 for the specified contracts. These two commodities have the largest futures trading volume and the highest production volume of all agricultural commodities providing a market with liquid, active spot and futures prices. This characteristic makes corn and soybeans good choices for a study concerning the commodity futures markets.

Data analysis included the use of Cumby and Modest's (1987) Timing Model, adjusted for Kolb's (1999) arbitrage bound, to determine whether futures prices consistently provide a higher/lower return to the producer than daily cash spot prices for corn (soybeans). This dissertation compared daily cash spot prices to the daily futures contract prices for 232 trading days prior to the beginning of the month in which the contract matures for thirty-one contract years for two corn futures contracts (September and December) and two soybean futures contracts (November and January).

The results of the timing model do not support the null hypothesis that "a time frame does not exist in which daily corn (soybean) futures prices are consistently higher/lower than the related daily cash spot price, after adjusting for an arbitrage bound." In fact, the results indicate that futures prices more often fall "below" the arbitrage lower bound limit than they do within or above the bound (see Table 4.1). The January soybean contract falls below the bound for all thirty-one years for trade days 1 through 21. These results suggest that some inefficiency may exist in the corn and soybean futures markets. However, different results may have occurred if intraday data or daily "next day" opening prices had been used instead of settlement data.

Data analysis also included the use of a mean-variance framework and a logarithmic utility function developed by Rolfo (1980) to calculate a hedge ratio for corn

and soybeans. Although Rolfo found that the mean-variance model yielded a higher hedge ratio than the logarithmic function (the mean-variance ratio is approximately double that of the logarithmic ratio), this dissertation found just the opposite. The September corn futures contracts and the November soybean futures contracts suggest that southern producers should hedge approximately 47% and 49% (mean-variance) or 83% and 76% (logarithmic), respectively. The December corn futures contracts and the January soybean futures contracts suggest that midwestern producers should hedge 21% and 102% (mean-variance) or 40% and 243% (logarithmic), respectively.

The January soybean futures contract results are substantially different from the results of the other three contracts. The suggestion that producers should hedge more than 100% using January soybean contracts may be attributable to the fact that the covariance of the price error forecast with the quantity forecast, and the variance of the price error forecast, were almost equal.

The ratios derived from both hedge models do not support the null hypothesis that “a partial hedge will not consistently allow a producer to receive a higher average price than a full hedge of expected corn (soybeans) yield.” Specifically, the results from three contracts indicate that producers should hedge less than 100% of their expected output while the results from the other contract (January soybeans) indicate that producers should hedge more than 100% of their expected output.

Section 2: Limitations and Suggestions for Future Research

The models used in this dissertation are applied to two corn futures contracts (September and December) and two soybean futures contracts (November and January). There is no reason to believe that corn and soybean futures are not representative of other actively traded grain futures or of each other.

Testing in this dissertation is limited to the years 1970 - 2000 due to data availability. The use of additional years of data or the use of different contract months may result in different conclusions regarding the null hypothesis that daily futures prices do not consistently provide higher/lower prices than daily cash spot prices, after adjusting for an arbitrage bound. The use of additional years of data may also result in a different conclusion regarding the null hypothesis that a partial hedge will not consistently allow a producer to receive a higher average price than a full hedge of expected corn (soybeans) yield; the current results support the rejection of the null hypothesis.

Future research should extend this dissertation to the remaining contract months for both corn (March, May and July) and soybean (March, May, July, August, and September) contracts. Additionally, this dissertation could be extended to wheat, oats, cotton, and other commodity futures contracts.

APPENDIX A

**LITERATURE REVIEW ADDRESSING THE
EFFECTS OF U.S. AGRICULTURAL
POLICY ON COMMODITY PRICES
AND PRODUCTION**

Exhibit A.1: Crop Subsidies

Herriges, Barickman, & Shogren (1992)	Study the value of corn base acreage. Believe because base acreage provides the only access to price support programs, land values incorporate both current and expected revenue from these programs. Find that rental payments for "corn base acreage" land in Iowa are approximately \$11-\$13 (per acre per year) higher than for comparable land without access to support programs; this accounts for approximately 11-14% of estimated land values.
Just & Miranowski (1993)	Develop a structural model of land prices to understand changes in (farm) land values. Indicate government support payments may account for roughly 15-25% of land values. Because Congress has passed legislation for the last 50 years to continue direct government payments for certain crops, both producers and landowners can reasonably expect this policy to continue. Thus, subsidies do not explain large fluctuations in land prices.
Lamb (1997)	FAIR substantially reduces direct commodity price support payments to U.S. commodity producers of program crops (i.e., corn, wheat, cotton, rice, sorghum, barley, and oats) beginning with 1998 and extending through 2002. By the last year addressed in the current legislation, Congress expects to pay approximately \$4.0 billion in crop subsidies; under a 1990 farm bill, Congress budgeted \$7.8 billion for crop subsidies for the same time period.
Barnard, Whittaker, Westernbarger, & Ahearn (1997)	Find the effects of FAIR on crop land values will vary across the country, primarily as a result of the dominant local crop. A portion of the decrease in land value may be offset by increased efficiency resulting from more flexibility in changing the type of crops planted each year, continued productivity gains, and strong export demand.
Smith & Glauber (1998)	On average, direct government payments account for less than 5% of total producer cash income during the five-year period 1991-1995. Question effectiveness of deficiency payments in providing revenue protection because the payment depends on the degree to which a producer's yield correlates with aggregate yield and price. Most private and government analyses indicate FAIR will create little change in acreage planted or prices for wheat and food grains.
Skees (1999)	Questions economic reasoning behind any crop subsidy in a discussion of federal crop insurance. Competition for a 'good deal' reduces wages, raises asset values, and lowers crop prices from the subsidized sector just enough to offset the benefits of the subsidies. New competition restores wages, profits, and land rents to their original levels; thus, subsidies merely reallocate factors from one part of the economy to another (from other areas to farming) and the landowner, not the producer, receives the subsidy benefit.

Exhibit A.2: Government Policy and Production

McKinnon (1967)	Indicates the government's myopic focus on spot prices and a corresponding disinterest in futures trading has led to inefficient and unsuccessful past attempts to stabilize prices. Believes the government and other parties interested in stabilizing prices should confine their activities to stabilizing distant futures prices; public policy should encourage active futures trading, particularly by primary producers. This practice would negate the need for existing complex and inefficient commodity programs. The futures market permits a more efficient allocation of commodity resources while simultaneously minimizing price risk for producers.
Romer (1991)	Reviews the cyclical nature of production for 38 items, including corn, wheat, oats, cotton, etc. Seeks to identify the size, source, and correlation of production fluctuations for the period 1889-1984. No agricultural commodity exhibits any stabilization in production volume over the 95-year period examined except hay and Irish potatoes. Questions whether government intervention to stabilize the economy since the world wars has reduced the size of or the response to such shocks. Factor analysis indicates a common factor (to mining, manufacturing, etc.) provides less explanatory power for agricultural commodities than for other types of goods. This supports the theory that an industry (or commodity) specific shock affects agricultural production. Since World War II, agricultural production has changed from mildly procyclical to mildly countercyclical.
Khoury & Yourougou (1993)	Study the effect of five sources of agricultural futures markets volatility identified in the literature: the year, calendar month, contract month, maturity, and trading session effects. Review the canola, rye, feed barley, feed wheat, flaxseed, and oats futures markets. (Note: Winnipeg conducts the only flaxseed market in North America and the only canola, barley, and rye markets in the world.) Results indicate each of the five sources of volatility influence the volatility in each of the futures markets in the study. Results suggest Wheat Board intervention reduces, but does not eliminate, the year, maturity, and trading session effects for wheat, barley, and oats, but has no impact on the month or contract effects.

Crain & Lee (1996)	<p>Study the impact of 13 farm programs on volatility of wheat spot and futures prices by dividing the programs into three periods (1/50 - 4/64; 4/64 - 12/85; and 12/85 - 12/93). Period 2 displays the highest and period 1 displays the lowest spot-futures volatility. Believe mandatory acreage allotments in the 50's and early 60's as compared to voluntary programs in the mid to late 60's contributes to the increased volatility of both spot and futures wheat prices. Results indicate seasonal volatility in the wheat market. However, government programs are more significant to price volatility than seasonality. Evidence supports a transfer of volatility from the futures market to the spot market; this causal relationship has strengthened over time and has the strongest impact in period 3. Believe recent implementation of more market-driven farm policies has caused this closer alignment of spot and futures prices. Spot market volatility lags futures market volatility by up to 10 days.</p>
Herendeen & Hallberg (1997)	<p>Believe past agricultural price supports and production controls dealt with symptoms of agricultural distress and not the causes; also believe past programs reduced low-cost U.S. producer output while higher-cost Japanese and European producers faced few, if any, output restraints. Draw these conclusions: 1) agricultural output/ prices exhibit greater volatility than aggregate output/prices; 2) in the 1970s and 1980s, only a loose relationship existed between the aggregate business cycle and the agricultural business cycle- instead, the agricultural cycle closely follows the business cycle for raw materials producers; 3) the monetary and fiscal policy pursued by the U.S. (and other major countries) relating to real interest rates, changes in currency values and changes in overall world demand for basic commodities, provided the driving force behind the agricultural business cycle of the 1970s and 1980s; 4) the 1980s farm credit crisis resulted from an expansion of farm debt based on an increase in farm income due to a combination of falling interest rates and rising prices/yields—the rise in interest rates and the fall in crop prices, caused the value of land to collapse; 5) a high correlation existed between real agricultural exports and the inverse of the value of the dollar; thus, domestic prices increased or decreased as the dollar rose or fell. Because grains are exported (in grain and oil form) and used as feed for livestock, which is also exported, changes in export prices have effects extending beyond the portion of the crop actually exported. Believe future world demand for commodities, the value of the dollar, real interest rates, and the reaction of other major countries producing crops will determine whether U.S. government intervention in agriculture will diminish as a result of the FAIR Act.</p>

Adam, Betts, & Brorsen (2000)	Study the effects of a reduction in government deficiency payments on wheat producer's post-harvest marketing plans. (They do not evaluate the effect on producer's use of futures contracts in pre-harvest marketing strategies.) Report that wheat producers did sustain a revenue loss from the elimination of these deficiency payments. Find that the deficiency payment program was no more effective than other approaches in reducing revenue risk associated with post-harvest grain storage.
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APPENDIX B

**LITERATURE REVIEW ADDRESSING THE
EFFECTS OF U.S. AGRICULTURAL
EFFICIENCY OF THE COMMODITY
FUTURES MARKETS**

**Exhibit B.1: Summary of Commodity Futures Market
Efficiency Literature: General**

Tomek & Gray (1970)	State that all other things being equal, the allocative and forward pricing function of futures markets will be more reliable for continuous (corn, soybeans, etc.) than for discontinuous (Maine potatoes) inventory markets. Carrying continuous inventories results in daily price spread movements affecting all future delivery months “smoothly”; it also interacts with inventory adjustments and contributes to pricing efficiency.
Kofi (1973)	Develops framework to assess the efficiency of futures markets and empirically compares the relative performance of Chicago wheat, Maine potatoes, cocoa, coffee, soybeans, and corn. Finds “. . . that futures markets perform their forward pricing function very well and that the correlation coefficient measures well the degree to which the spot (cash) price is predictable months in advance for a particular commodity.” States, “The predictive reliability of a futures market improves as more accurate information on supply and demand becomes available.” Believes markets’ price setting function includes market participants’ opinions of the significance of developing economic information in a changing world.
Taylor (1985)	Indicates the simplicity of standard autocorrelation tests makes them attractive, but conclusions based on them are unreliable due to false assumptions they require. Tests suggest risk premia may exist at the London markets, while no evidence exists for premia in the Chicago or Sydney markets. Also, no futures experience significant average decreases on Mondays but currency futures rise on Wednesdays and fall on Thursday due to the clearing system used. The standard deviation for Monday’s return is ≈ 1.12 times the standard deviation on other days. The standard deviation does not appear to increase systematically during the final six months of the futures contracts. Corn prices from 1963 to 1976 exhibit evidence of positive autocorrelation. However, this does not contradict the EMH if trading costs exceed gross trading gains. Indicates assessing the efficiency of any market is difficult because no one has described the evidence required to reject market efficiency conclusively. Because of the unknown distribution of returns from the filter strategy, it is impossible to perform the proper significance tests. Also, the selection of the filter parameter presents a problem. Trading rules assessments indicate inefficiency in the sugar market; results in other markets do not provide sufficient evidence to reject efficiency.

Hall, Brorsen, & Irwin (1989)	Tests of two hypotheses proposed to explain leptokurticity in futures price movements distributions, the stable Paretian and mixture of normals, suggest dependence in price changes explains the leptokurtic distribution. Tests applied to financial, metal and agricultural futures using date sequence data show a leptokurtic distribution of the sums of the data while randomized data tests indicate a normal distribution of the sums of the data. Suggest that because autocorrelation in futures prices is small, serial correlation of the variance provides the most likely reason for rejecting independence in price changes.
Johnson, Zulauf, Irwin, & Gerlow (1991)	Test for trading profits by applying a profit margin trading rule to the intercommodity spread of soybeans, soyoil, and soymeal (the soy complex). The trade rule initiates trades when a pre-specified implied profit exists (profit calculated from currently-quoted futures prices for the output of the production process and estimated production costs). Results suggest weak-form efficiency of nearby soy complex futures price spreads but the inefficiency of distant soy complex futures price spreads; indicates soy complex futures spreads are not unbiased forecasts over longer time periods.
DeCoster, Labys, & Mitchell (1992)	Use a correlation dimension technique to search for chaotic structure in daily futures prices for sugar, coffee, silver, and copper. Results indicate the presence of nonlinear structure in the data; the present structure does not suggest heteroscedasticity. Evidence of structure raises questions about the efficiency of futures markets as it creates a possibility that profitable, nonlinear trading rules exist.
Deaton & Laroque (1992)	Report explanatory capability of the standard rational expectations competitive storage model for such facts as skewness and the existence of rare but violent price explosions; however, the model does not provide a completely satisfactory explanation for the high price autocorrelation (year-to-year) found in more normal times. The model explicitly recognizes the market as a whole cannot carry negative inventories of commodities; this fact introduces non-linearity into any (predicted or actual) commodity price series. Results indicate the price behavior for most of the 13 commodities analyzed conforms to price behavior predictions based on the theory of conditional expectations and conditional variances.

Goss, Avsar, & Chan (1992)	Develop a simultaneous rational expectations model of the US oats market. The model includes separate functional relationships for short and long hedgers, net long speculators in futures, holders of unhedged inventories, and consumers. Test results provide support for the rational expectations hypothesis except in the case of short hedgers; however, the evidence supports the adaptive hypothesis for short hedgers. Find hedged stocks respond more to price changes than unhedged stocks and net long and short speculative positions respond similarly to changes in futures prices. Results from a post-sample forecast of cash prices based on the model do not provide evidence that rejects the semi-strong EMH for the U.S. oat market.
Gay, Kale, Kolb, & Noe (1994)	Examine futures price reactions to news stories about commodities exhibiting unusual trading volume during the previous business day. Results indicate headlines reflecting a bear market result in a greater price impact than headlines suggesting a bull market. Find prices fall and then reverse, with the reversal positively related to the magnitude of the opening price change, following "bear" headlines. Also, the magnitude of the opening price change displays a positive relationship with trading volume. Results suggest the implementation of trading rules could provide economic profit by exploiting the opening price of the contract.
Deaton & Laroque (1996)	Test a price formation model which acknowledges speculative storage moderates supply and demand shocks. Speculative storage should also change the variability of commodity prices. However, results reject the hypothesis that speculator behavior could explain the observed high price autocorrelation and they also reject the idea that a combination of both speculator activity and the driving processes of supply and demand could explain the autocorrelation. Conclude that while speculation may increase the existing autocorrelation, it is not the only source of the autocorrelation.
Garcia, Irwin, Leuthold, & Yang (1997)	Test informational value of USDA corn and soybean production forecasts as compared to private crop forecasts. Perform three tests: 1) the relative forecast accuracy test suggests the USDA and private forecasts have a similar level of accuracy; 2) a price reaction test shows the unanticipated component of USDA forecasts significantly affects corn and soybean futures prices to a greater extent than an unanticipated component of a private forecast; and 3) the willingness-to-pay test indicates traders are willing to pay for advance knowledge of USDA forecasts. Results indicate the informational value of USDA forecasts has steadily declined since the mid 1980s.

Perrakis & Khoury (1998)	Develop and test a model to determine the theoretical and empirical implications of the existence of asymmetric information in the Winnipeg commodity futures markets. Results indicate information asymmetry relating to known spot supplies does not exist in the canola and barley markets; however, results provide evidence of information asymmetry in the oats market. Believe the oat market results may be caused by the influence of the large trading volume in the Chicago market; in contrast, Winnipeg is the primary trading market for canola and barley.
Chan & Lien (2002)	Before 1986, the CME required the settlement of all opening positions on feeder cattle futures contracts with physical delivery after the last trading day. Due to diminishing commercial interests, the CME replaced that system in 1986 with a cash settlement system. They use stochastic volatility models to determine if this change from physical delivery to a cash settlement system would improve the convergence of cash spot and futures prices and decrease the basis variability. They find both a reduction in basis and in basis variance as well as a change in the relationship between cash and futures prices. These results support the supposition that the change to a cash settlement would result in a more efficient futures market.

Exhibit B.2: Summary of Commodity Futures Market Efficiency Literature: Seasonal and Other Anomalies

Anderson & Danthine (1983)	Attempt to clarify the meaning of the Samuelson hypothesis using a three-trade date rational expectations model of <i>diverse</i> information. Results indicate the resolution of large amounts of uncertainty creates volatility while the resolution of small amounts of uncertainty does not cause volatility. Argues when large amounts of uncertainty resolve early in the life of a contract, then volatility decreases as the maturity date approaches.
Anderson (1985)	Uses futures market data (includes wheat, corn, oats, and soybean prices) to study daily price change volatility and finds the variance of futures price changes is not constant; however, changes in variance follow a partially predictable pattern. Seasonality is the principle predictable factor for this pattern and the changing time to maturity is a secondary factor.
Ferris & Chance (1987)	Confirm a slight negative Monday trading effect for soybeans. Evidence indicates higher day-to-day trading volatility on Monday relative to other trading days for soybeans. Volatility appears significantly higher (2-3 times higher) during trading hours vs. overnights and weekends for all soybean contract trading.
Milonas (1991)	Test results for a “half-month” effect (positive average return in first half of month that is significantly higher than for second half of month) for corn and wheat indicate a statistically significant positive average logarithmic return for the first half of the month and a negative return for the second half.
Stevens (1991)	Results indicate soybean, corn, and wheat prices do not vary as a random walk during the growing season. Believes persistent growing season weather conditions arrive with a degree of momentum and induce similar momentum into commodity prices.
Galloway & Kolb (1996)	Test for a maturity effect after controlling for the effects of year, calendar month, and contract month. Results provide strong support for a maturity effect in agricultural commodities. Indicate the maturity effect may play a significant role in commodity price volatility for items which experience seasonal supply or demand.

Hennessy & Wahl (1996)	Test to see if futures contracts of a long duration allow producers to receive and act upon futures price volatility patterns that emerge as contracts near maturity. Show that seasonality arises from increasingly constrained supply/demand functions as the maturity date approaches and not from resolved uncertainty about supply. Indicate resolution of supply and demand uncertainty may increase, not decrease, price volatility. Suggest decisions made on the supply (demand) side makes future supply/demand responses less elastic; supply/demand shocks occurring after making a decision (i.e., acreage planted, contracts purchased, etc.) has more effect on a futures price than a shock before making the decision.
Black & Tonks (2000)	Extend the test of the Samuelson hypothesis using a three-trade date rational expectations model of <i>asymmetric</i> information to distinguish between the effects of uncertainty and informational efficiency. Find that if a large amount of output uncertainty is resolved by the second trade date and if the market is informationally efficient, then volatility will decrease as the maturity date approaches, thus violating the Samuelson hypothesis. However, if the market is informationally inefficient, the Samuelson hypothesis will hold.
Goodwin & Schnepf (2000)	Documents sources of price variability in the U.S. corn and wheat futures markets. The results of both a conditional heteroscedasticity and a nonstructural vector autoregressive model indicate corn and wheat price variability is significantly related to the ratio of use to stocks, futures market activity, and growing conditions (strongest effect). They find that above-average crop conditions tend to produce lower levels of price variability; they also identify a strong seasonality in corn and wheat price variations with the highest variation peaks occurring in the summer.

Exhibit B.3: Summary of Commodity Futures Market Efficiency Literature: Tests of Market Cointegration

Pindyck & Rotemberg (1990)	Results indicate a statistically significant correlation between: gold prices and copper/crude oil/lumber/cocoa prices; cotton prices and copper/lumber/wheat prices; and between lumber prices and copper/cocoa prices. Identified co-movement exceeds anything aggregate demand changes, interest rate, inflation, or exchange rate changes might explain. Possible explanations include: 1) liquidity constraints play a part—when one commodity's price falls, it lowers the price of others and hurts investors long in several commodities simultaneously; 2) investors in different commodities react similarly to non-economic factors; 3) commodity prices include large amounts of high-frequency, mean-reverting noise.
Peterson, Ma, & Ritchey (1992)	Test results of the random walk hypothesis for wheat, cotton, corn, oats, soybeans, soybean oil, and soybean meal cash prices reject the hypothesis for daily agricultural commodity prices and suggest positive serial correlation between successive price changes which underlying economic factors do not explain. Results support positive serial correlation in price changes over short and intermediate time horizons suggesting: 1) daily commodity prices may not react rationally to unexpected information; 2) the adjustment process for transaction costs is not instantaneous; or 3) investors do not properly anticipate information revealed in a serially correlated fashion.
Fortenbery & Zapata (1993)	Examine the cash/futures price relationship for corn and soybeans using two cash markets and the CBOT futures markets for each commodity. While results from the aggregate data support cointegration between the futures and cash markets, results reported by crop year indicate cointegration exists when minimal differences exist between the local and futures markets (i.e., drought years) but does not exist otherwise. Also, results indicate no profitable arbitrage opportunities exist between any of the markets.
Arguea & Harper (1994)	Examine the statistical relationship between world and U.S. sugar futures contracts traded on the CSCE. Results indicate when the U.S. imposes tariffs on imports, world and U.S. sugar price exhibit strong linkages; however, when the U.S. operates under a quota program (insulating the U.S. from world price changes), linkages are not evident. World prices appear to lead U.S. prices under the tariff period but the U.S. market does not appear to influence world prices under either the quota or tariff period.

Tomek (1994)	Comments on Peterson, et al.'s (1992) analysis of cash commodity prices statistical properties. Says cash prices should not follow a random walk and this model is inappropriate for testing cash market efficiency. Indicates good reasons exist for autocorrelation in commodity prices; reasons include the supply/demand relationship for commodities or dynamics associated with transaction costs as new information creates changes in prices. Disagrees with the authors that some component separate from the underlying fundamentals can be used to predict future prices. States systematic patterns probably reflect transaction costs or some other market fundamental in complex markets.
Beck (1994)	Uses cointegration techniques to test market efficiency in the cocoa, live cattle, frozen orange juice concentrate, copper, and corn spot and eight week futures price markets. Although results provide evidence of inefficiency in all five markets at certain times, none reject efficiency all the time. Results from the error correction model (ECM) indicate that cases where ECM rejects unbiasedness correspond to those markets that reject efficiency as well; this indicates that inefficiency, rather than the presence of risk premia, causes the rejection of unbiasedness in commodities futures prices.
Leybourne, Lloyd, & Reed (1994)	Present a conceptual framework for identifying/testing an excess co-movement hypothesis and propose a rigorous definition of co-movement that says prices co-move if those prices are cointegrated with a positive cointegration parameter. Test 12 commodities, including cotton, sugar, and wheat, for co-movement. Since results show co-movement only between lumber and cocoa, the tests reject the idea of widespread, excess co-movement between commodities.
Karbus & Jumah (1995)	Examine the long-run relationship between futures and spot prices of cocoa and coffee on both the CSCE and the London Fox. Find cointegration between the prices of coffee and cocoa in the long run. Results also support the law of one price (LOP) for cocoa spot and futures prices; however, the results only provide weak support for the LOP for coffee futures. Believe weak support for the LOP for coffee futures results from a difference in the type of coffee beans traded on the CSCE (arabica) vs. the London Fox (robusta).

Brenner & Kroner (1995)	Incorporate use of a no-arbitrage, cost-of-carry asset pricing model that shows the existence of cointegration between spot and futures prices depends on the time-series properties of the cost-of-carry. Examine four of the existing tests for the unbiasedness hypothesis in the financial markets and use the cointegration results to show why these tests reject unbiasedness. Provide an overview of recent articles relating to cointegration in commodity markets.
Malliaris & Urrutia (1996)	Investigate short and long-term relationships for corn, wheat, oats, soybean, soybean meal, and soybean oil contracts traded on the CBOT. Results indicate cointegration of the time series of prices; the ECM strongly supports statistically significant relationships between each of the commodities tested but finds no short-term causality. Believe this dependency in prices between commodities relates to the ability to substitute one grain for another (especially for feed grain purposes) and the complementary properties of the grains (i.e., the nutrients in corn complement the nutrients found in soybeans). Indicate the price discovery function for one commodity futures contract also provides relevant information for other related commodity futures contracts.
Hudson, Elam, Ethridge, & Brown (1996)	Examine a cash/futures price relationship between cotton futures prices as compared to cotton cash prices for the southwest region. Results indicate cointegration exists in two years (the first and last years in the sample) and does not exist in the other two (the middle two years). Additional tests reveal that, in the presence of cointegration, the futures market leads the cash market.
Barkoulas, Labys, & Onochie (1997)	Use monthly cash prices to test for long memory across commodity spot prices. Results confirm fractional orders of integration for soybeans, copper, and tea. It may be possible to construct time series models to take advantage of these fractional integers. Results also indicate the fractional orders may vary among the different series, maybe because different processes generate price movements for different commodities. Also, conclude the existence of fractional dynamics in spot prices makes the use of linear price models questionable and indicate a need to develop a nonlinear price model to account for fractional behavior in prices. Believe discovery of a long memory property in a futures series may reflect statistical properties of other factors creating the spot prices and that the commodity market processes which contain long-term dependence, in fact, generate these factors; if true, this reopens the debate of pricing efficiency and market rationality in commodity futures markets.

Fortenbery & Zapata (1997)	Evaluate price linkages between cheddar cheese futures and cash markets to determine if one market dominates the other in the price discovery function and overall pricing behavior. Results provide no support for a stable long-run relationship between cash and futures markets for cheddar cheese. While this may result from the relative immaturity of the market (test period coincides with beginning of futures trading in cheddar cheese), two other new futures markets (fertilizer products) become closely linked with the respective cash markets within one year.
Chaudhry & Christie-David (1998)	Investigate long-run stochastic properties of informationally linked futures contracts in diverse groups such as soft commodities (sugar, cocoa, coffee, orange juice), grain and oilseeds (wheat, soybean oil, and oats), livestock (cattle, hogs, and pork bellies), and other non-agricultural commodities. Results provide weak evidence of cointegration within the grain and oilseeds group and the livestock group. Find evidence supporting cointegration among the three agricultural groups and the results indicate the presence of at least one cointegrating vector among the three groups and the Commodities Research Bureau index.
Yang & Leatham (1998)	Examine the EMH as it relates to U.S. grain markets - particularly whether cointegration exists among grain spot prices. Conduct bivariate and multivariate Johansen cointegration analyses - find no evidence of cointegration between corn, oat, wheat, and soybean U.S. grain markets. Results support the EMH.
Chow (1998)	Proposes a regime switching model of spot prices. Shows that Monte Carlo experiments which test for cointegration and estimates of the cointegrating vector may be biased when a sample has infrequent changes in regime. After consideration of these items, the results support the cointegration of spot and futures prices; these prices move together in the long-run.
Malliaris & Urrutia (1998)	Conduct tests of cointegration between price and volume for oats, corn, wheat, soybeans, soybean meal, and soybean oil commodity futures contracts. Data supports cointegration between price and volume with a stronger long-run relationship from price to volume; this suggests trading volume tends to follow and adjust to price in the long-run. The ECM supports bidirectional causality between price and volume in the long-run. Results also indicate that of three factors tested (time trend, price, and volatility), only price volatility produces a statistically significant impact on trading volume. Also find price volatility significantly impacts volume volatility.

Thraen (1999)	Extends Fortenbery and Zapata's study (1997) regarding cheddar cheese market efficiency. Finds cointegration parameters in the cheddar cheese markets converge after approximately 126 weeks of trading (i.e., about two and one-half years); this provides support for efficiency in this market.
Kellard, Newbold, Rayner, & Ennew (1999)	Define an efficient commodity market as one yielding futures prices that are an optimal forecast of the expected future spot price except to the extent that a random unpredictable zero-mean error exists. Results suggest cointegration of spot and futures prices in the live hog, soybean, and live cattle markets. This long-run cointegrated relationship may not hold in the short run since a lagged difference in the spot and futures prices as well as the basis can explain some changes in the spot price. Additional tests support the efficiency of the soybean market and the inefficiency of the live cattle market; although the hog market also exhibits inefficiency, the results indicate it is less inefficient than the live cattle market.
Crato & Ray's (2000)	Although reexamination of the data set used by Barkoulas, et al. finds no evidence supporting the existence of long memory in futures' returns, results do support the existence of long-memory behavior in the volatility of futures' returns.
Goodwin & Piggott (2001)	State that transactions costs may create a "neutral band" within which prices are not linked to one another." Evaluation of regional corn and soybean markets in North Carolina for spatial linkages and daily price dynamics confirm a tight integration of these markets; price adjustments generally occur within fifteen days. Also indicate transactions costs may form a neutral band that results in a well integrated market even though market prices are not directly linked.
Yang, Bessler, & Leatham (2001)	This study allows for the compounding factor of stochastic interest rates and focuses on the price discovery performance of futures markets for both storable and nonstorable commodities. The findings support the theory that futures prices provide an unbiased predictor of future cash prices in the long run for the storable commodities tested (corn, oats, soybeans, cotton, and pork bellies); the results indicate futures prices lead cash prices in the long run. However, futures prices do not provide an unbiased predictor of future cash prices for most livestock markets and thus, producers should use futures prices cautiously in making production decisions.

Thompson, Sui, & Bohl (2002)	The degree of spatial efficiency between commodity markets has important implications for market operations and policy reforms. They investigate the degree of spatial equilibrium between three European Union (EU) wheat markets and how policy reforms affect the speed of adjustment between the markets long-run price relationships. They use a seemingly unrelated cointegration test (SUADF) and a seemingly unrelated error correction model (SURECM). The results from these tests indicate spatial equilibrium exists in the EU wheat markets and policy liberalizing reforms allow a more rapid convergence of world prices.
McKenzie & Holt (2002)	Using both cointegration and error correction models, they test the live cattle, hogs, corn and soybean meal futures markets for market efficiency and unbiasedness. Although their results support both efficiency and unbiasedness in all markets in the long run, they find some inefficiencies and pricing biases (i.e., normal backwardation) in the short run in the corn and live cattle futures markets.

Exhibit B.4: Summary of Commodity Futures Market Efficiency Literature: Tests of Mean Reversion

Dorfman (1993)	Most studies pose the null hypothesis of the EMH as a statistical relationship that asset prices follow a random walk. If asset prices follow a random walk, investors cannot profitably predict prices. The alternative indicates the time series of prices tends to exhibit mean reversion. Mean reversion requires rejection of the EMH because investors observing deviations from the mean would buy/sell the asset currently to allow the realization of a profit when the asset price reverts to the mean. Results from a nonparametric Bayesian test reject market efficiency; also, the futures market does not exhibit more or less efficiency as the contract nears expiration.
Bessembinder, Avsar, & Chan (1995)	Use price data from futures contracts with varying delivery horizons to determine if investors expect futures prices to revert. Methodology focuses on the relationship between the slope of the futures term structure (across delivery dates) and price levels on a given trading date. Test results for metal, oil, and agricultural commodities indicate mean reversion in spot prices occurs and the reversion arises solely from positive co-movement between prices and implied cash flow yields.
Irwin, Zulauf, & Jackson (1996)	Apply both a regression test of mean reversion to changes in corn, soybean, wheat, live hog, and live cattle commodity futures prices and Monte Carlo simulations to generate small sample distributions of regression parameters and test statistics (based on null hypothesis of no predictability in futures prices). Regression results strongly support mean reversion; Monte Carlo regression results do not support mean reversion at all.
Zhou (1998)	Says a hedging model makes two assumptions: It 1) considers only indispensable good commodities; 2) assumes producers have a liquidity constraint (i.e., their trading losses in the futures market cannot exceed a pre-specified level). Model hedge results indicate liquidity constraints may cause mean reversion in futures prices which then makes speculation profitable. Also, market speculation tends to make volatility an increasing function of the price level. Finally, when the government provides a price subsidy, the effect of the subsidy depends on the liquidity constraints faced by producers participating in the market. If producers do not face a trading loss liquidity constraint, subsidies cause a negative expected return on the futures price and reduces overall price volatility; this effect occurs most often when the futures price just equals or is slightly below the governmental price subsidy level.

Exhibit B.5: Summary of Commodity Futures Market Efficiency Literature: Risk Premia, Backwardation, and Asset Pricing Models

Telser (1958)	Tests for a trend in futures contracts for wheat and cotton. Results reject the theory of backwardation and supports the idea that no trend exists in futures prices.
Dusak (1973)	Calculates individual commodity betas for five contracts each for wheat, corn, and soybeans. None of the betas differ significantly from zero. Says these results support the hypothesis that futures prices provide an unbiased estimator of the future spot price.
Bodie & Rosansky (1980)	Examine returns distribution for 23 commodity futures contracts. Results indicate contracts yield a positive mean excess (above the risk-free rate on T-bills) return which lends support to the normal backwardation hypothesis. However, the relationship between the means and the calculated beta coefficients does not support the conventional form of CAPM. Also, the mean rate of return on a diversified commodity futures portfolio provides a return well in excess of the average risk-free rate; it is close to the mean and variance of the S&P 500 common stock portfolio return.
Hazuka (1984)	Uses a consumption oriented CAPM to develop a linear relationship between consumption betas and risk premiums. Finds the model used for nonstorable commodities has great explanatory ability while seasonable storable commodity (corn, etc.) and non-seasonal storable commodity models do not provide any explanatory ability.
Chang (1985)	Employs a nonparametric test to examine returns to speculators in wheat, corn, and soybeans futures. Results are inconsistent with the hypothesis that commodity futures prices provide unbiased estimates of the corresponding future spot prices; instead, results support the theory of normal backwardation. Tests also indicate risk premiums exist in different degrees in different markets at different times and risk premiums are more prominent in recent years. Finally, indicates "large wheat speculators" possess some superior forecasting ability and the market rewards such skill.
Jagannathan (1985)	Uses the ICAPM to analyze prices for corn, wheat, and soybeans futures contracts. Reasons for rejecting the model include the: 1) asymptotic inference theory may not be justified due to the small sample size (monthly prices for 18 years); 2) agents may not possess/have access to the same information set; 3) model assumes a time separable utility function and that no shocks to preferences occur; 4) agent may not have frictionless access to markets as assumed; and 5) model ignores durable goods consumption due to measurement difficulties.

Fama & French (1987)	Little agreement exists on whether futures prices contain expected premiums or whether they provide unbiased estimates of future spot prices. Use both models to study the behavior of prices for various commodities. Find it is easier to detect a response of futures prices to storage cost variables than to obtain evidence that futures prices contain premiums or that futures prices forecast future expected spot prices. Results indicate soybean and animal product futures prices show some evidence of forecast power; tests of corn, wheat, and cocoa futures provide limited evidence that these futures prices include an expected premium.
Murphy & Hilliard (1989)	High positive excess returns on long commodity futures before 1974 may represent compensation for the indivisibility and large size of commodity futures contracts. These characteristics make it impossible for many investors to diversify the unsystematic risk associated with the investment in commodity futures contracts. Returns may also provide compensation for tax disadvantages related to investing in commodity futures vs. stocks. Results indicate excess returns for tax disadvantages and indivisibility disappear after 1974, perhaps due to the availability of mutual fund investments in commodity futures.
Kolb (1992)	Initially tests 29 commodities; finds seven support the theory of a risk premium. Three commodities exhibit contango (heating oil, crude oil, and lumber) while four indicate backwardation (live cattle, feeder cattle, live hogs, and orange juice).
Beck (1993)	Uses an intertemporal hedging model to test soybean, orange juice concentrate, live hog, live cattle, and silver prices at four forecast horizons. Results indicate significant constant risk premia exists for all cattle/soybean prices; at all forecast horizons except 8 weeks for orange juice; at all horizons except 12 weeks for silver; and at the 12-week horizon for hogs. The constant risk premium size tends to shrink for shorter horizons.
Bailey & Chan (1993)	Use systematic factors to explain variation in the spread between commodity spot and futures prices for agricultural crops, livestock, metals, lumber, and food products. Believe common elements affect basis variations across different commodities and that futures prices include not only the cash price, but also a risk premium for bearing the systematic risk associated with carrying the futures position. Results: 1) indicate the default yield spread in the bond market and the stock market dividend yield explain a large portion of the common futures market variation in basis and 2) suggests macroeconomic risks which affect stock and bond markets also affect risk premiums in commodity futures markets.

Cooper (1993)	Addresses problems with empirical rejections of the ICAPM. Methodology replaces the marginal rate of substitution with an index portfolio that avoids the use of noise and infrequently reported consumption data. Commodities tested include cocoa, soybeans, corn, wheat, and other non-agricultural futures contracts. Contrary to previous research, results demonstrate the superiority of ICAPM for futures and forward risk premia as opposed to single-period modeling for all futures contracts tested. This indicates previous rejections or other problems with ICAPM may relate to restrictive utility assumptions or poor consumption data.
Bessembinder (1993)	Evaluates whether asset portfolios and portfolios including futures lie on the same estimated security market line (SML). Evidence indicates a zero mean return for commodity futures. Tests three hypotheses: 1) expected futures returns are a linear function of futures' systematic risk - rejects using a single beta (simple regression of monthly returns against CRSP value-weighted index returns) but does not reject when using multiple betas (estimated by multiple regression of monthly futures returns on CRSP value-weighted index returns and six macroeconomic variables); 2) the linear function has a zero intercept - rejects; and 3) the risk premia equals those provided in asset markets. The results reject the joint hypotheses of a zero intercept, linearity, and risk premia equal to the asset market premia regardless of whether a single or multiple beta model was used. Concludes portfolios with futures do not lie on the same estimated SML as asset portfolios.
Kenyon, Jones, & McGuirk (1993)	Find that while December corn and November soybean future prices at planting time provide a good indication of harvest prices from 1952 - 1968, the futures prices did not provide a good forecast from 1974 - 1991. Conclude futures prices function as forward prices rather than price forecasters.
Deaves & Krinsky (1995)	Retest the same seven commodities Kolb (1992) tests using an additional five years of data to determine if the commodities continue to exhibit contango or backwardation properties. Although livestock commodities continue to fit the backwardation model, the other commodities no longer display the same properties. Question whether any commodity futures, other than livestock futures, contain consistent risk premiums.

de Roon, Nijman, & Veld (1998)	Analyze “differences in one-period risk premia for futures contracts with different maturities.” Results indicate heating oil has constant and negative risk premia implying an upward sloping term structure of yields. Tests of the German Mark do not provide evidence that supports rejection of the hypothesis that the risk premia differs from zero. Gold and soybean futures returns depend on the slope of the expected futures term structure; i.e., a long-term contract provides a higher/lower expected return relative to short-term contracts when a larger/smaller spread exists between the long- and short-term contracts. Mixed results for live cattle futures and for soybean and gold futures indicate the one factor model used does not explain the regression evidence or the average slope of the yield curve.
Zulauf, Irwin, Ropp, & Sberna (1999)	Reexamine the forecasting performance of spring prices for December corn and November soybean futures contracts using both a price-level and a percent-change model. While the price-level model indicates spring prices for November soybean futures contracts provide a biased forecast, the percent-change model indicates spring prices for both the December corn and November soybean futures contracts provide unbiased forecasts. State that when futures markets provide unbiased forecasts, an individual producer can use them as a guide in making production decisions and can expect not to suffer financial losses due to changes in prices between planting and harvest. However, when the markets provide biased forecasts, individual producers may suffer financial losses from a misallocation of resources unless they simultaneously hedge production. Finally, suggest that because both models have relatively low R^2 s for the 1973-1997 period, producers should search for additional information because futures markets do not predict future spot prices with any degree of accuracy.
Miffre (2000)	Uses a model which allows for variation through time in expected returns. Results strongly support the normal backwardation and contango theories; in particular, the results strongly support normal backwardation for corn, soybeans, and wheat. The tests provide little support for the hypothesis “that the futures price is an unbiased estimate of the maturity spot price,” but provide strong evidence of risk transfers from hedgers to speculators.

de Roon, Nijman, & Veld (2000)	Presents a model of the futures risk premia identifying hedging pressure variables and the covariance of futures returns with the market (S&P 500) return. Model includes hedging pressure within a specific futures market (i.e., corn) and other related markets (i.e., grain markets related to corn). After controlling for market risk, finds that hedging pressure variables significantly affect futures returns even when price pressure effects are also controlled. These hedging pressure effects also impact returns on the underlying assets.
Hranaiova and Tomek (2002)	After estimating the joint value of timing and location delivery options on corn futures contracts, the authors use that value in regression models to see how much these options influence basis variability on the first day of the futures contract maturity month. They also use econometric models to “see if the estimated implicit options values are useful in improving the forecasts of basis convergence over the 2-month period prior to maturity.” Results indicate that the joint value of the delivery options does explain some of the basis variability; however, the use of this variable in basis convergence forecasts does not significantly reduce basis risk.
Sorensen (2002)	Uses both time-series and cross-sectional characteristics of corn, soybean, and wheat prices to evaluate seasonality in commodity prices. His results suggest all futures contracts for soybeans and wheat display normal backwardation. However, while long contract maturities for corn also exhibit normal backwardation, short contract maturities for corn display contango properties. He also finds that an empirically significant negative relationship exists between convenience yields and inventory levels.

Exhibit B.6: Forecasting and Trading Strategies

Turner, Houston, & Shepherd (1992)	Use a Markov indicator based on historical probabilities of moving from one state to all other possible states. Results provide evidence supporting correlation in the indicated market elements. Thus, information regarding open interest or trading volume may assist traders in forecasting future price change directions.
Borensztein & Reinhart (1994)	Studies stressing a structural approach to commodity price formation find the state of the business cycle in industrial countries and the real exchange rate of the U.S. dollar (two demand-side variables) explain much of the variation of commodity prices. After 1984, however, the economy in many industrial nations strengthened while commodity prices remained weak. Include commodity supplies and Eastern European/Soviet output in a price model. Revised model outperforms a random walk forecast for longer-term horizons; correctly forecasts major price turning points.
Leuthold, Garcia, & Lu (1994)	Assess the forecasting ability of large traders in the frozen pork bellies futures market by testing for consistent forecast ability and for "big hit" ability. Find that a subset of large elite traders possess significant forecasting ability; not only were these elite traders able to accurately forecast the direction of price changes consistently, but they also take the "correct" position when large price changes occur.
Ntungo & Boyd (1998)	Test application of a neural network as a commodity trading method by comparing forecast results to results obtained from a more traditional ARIMA model for corn, silver, and deutsche marks. Both models produce positive returns at approximately the same level; the trading rule may contribute to these positive results. Another contributing factor to the positive returns may be disequilibrium in the various markets. Indicate that because neural networks require subjective estimates for various parameters and estimation procedures, no two studies will produce the same results.

Hilliard & Reis (1998)	Analyze effect of including stochastic interest rates in a futures price forecast model. Indicate forecasted futures price will differ from futures price forecasts produced by a two-factor stochastic convenience yield model. The price difference depends on volatility of the interest rate process, correlation between spot prices and interest rates, and correlation between interest rates and convenience yields. However, the forecasted forward price using a two-factor model does not differ significantly from the price forecast of the three-factor model which includes the stochastic interest rate. Finally, results indicate jumps in the spot price process do not significantly affect forward or futures prices.
Elfakhani, Wionzek, & Chaudhury (1999)	Examine whether thin trading in Canadian canola and feed wheat futures markets creates profit opportunities for traders as compared to high trading volume in soybean oil and wheat futures at the CBOT. Test weak and semi-strong forms of the EMH by constructing a model (both full and reduced) to predict the next day futures prices. A comparison of forecasted and benchmark prices (i.e., actual opening or closing prices) identifies possible over or undervalued futures. Make trades based on identified opportunities using both a confidence interval and a percentage change filter trading rule. After considering transaction costs, find no profitable mispricing opportunities for any of the four commodities; does not reject the EMH. However, results indicate the most important predicting variable in forecasting price for each commodity is the daily opening price and that canola and soybean oil futures prices experience variable seasonality while wheat and feed wheat did not. This observation indicates a forecasting model for canola and soybeans oil futures prices must include a longer estimation period to account for seasonality.

APPENDIX C
LITERATURE REVIEW ADDRESSING
HEDGING STRATEGIES

Exhibit C.1.: Hedging Strategies

Peck (1975)	Recognizes that although year to year futures prices at planting time for some commodities are virtually constant (i.e., potatoes), the planting time quotes for new crop futures for soybeans and corn vary almost as much as cash harvest prices. Believes commodity producers should consider hedging to eliminate price risk after making the production decision assuming producers acknowledge year to year price variability when deciding on the mix of crops for the current year. Results of a price hedging strategy for eggs indicates “hedging all output over the production period appears to be a reasonable method of stabilizing revenues which does not depend on interpreting a price forecast.”
Rolfo (1980)	Looks at hedging ratios under price and quantity uncertainty for a cocoa producer. Results (using both a logarithmic utility function and a mean-variance framework) suggest a hedge ratio well below unity due to production uncertainty. Indicates quantity uncertainty may well explain the historic lack of interest by U.S. producers in hedging expected crop output.
Ho (1984)	Uses a continuous-time investment and consumption model to analyze the optimal use of futures in the hedging process when both price and output uncertainty exists. Futures trading provides a perfect hedge only if perfect correlation exists between price/output or when no output uncertainty exists. Results indicate the hedging ratio is less than one and falls as the time to harvest increases. Finally, believes producers benefit from a financial instrument such as a <i>commodity output index</i> to hedge output risk. Using the futures market to hedge price risk and an index to hedge output risk provides the producer with an opportunity to minimize both price and output risk.
Kamara & Seigel (1987)	Show the assumption that the distribution of spot and futures price changes is independent of when the hedge is put into place and the length of the hedge is inappropriate when contracts can be filled with one of several different grades. Propose a model to compute a theoretically correct hedge ratio which they apply to a sample of wheat futures. Results indicate the model performs better than a simple full hedge of expected quantities; however, do not provide a comparison of their model’s results and a simple regression hedge.
Gardner (1989)	Evaluates the effectiveness of rollover (between years) hedging for locking in a price. Results indicate that 3-year rollover hedges yield lower prices than what the producer can obtain by locking in prices annually for the period from 1972 - 1987. Note: the study does not consider price levels before locking in hedging strategies.

Vukina (1992)	Key question regarding the EMH relates to whether any one trader can generate higher returns than other traders due to an ability to correctly predict price movements; tests whether traders can use price forecasts to prepare/implement a hedging strategy to increase profits from hedging. Results of three hedging strategies indicate hedging the entire inventory (routine hedging) outperforms a no hedge strategy while selective hedging (using one of three different selective hedging models (two multivariate models – a cash + futures model and a cash + basis model; and a scalar model based on futures only) outperforms routine hedging. Results from the selective hedging models indicate the multivariate models perform equally and they generate higher profits than the scalar model.
Viswanath & Chatterjee (1992)	Extend the work of Kamara & Siegel (1987) and compare results obtained from hedging based on the K&S model to results obtained from hedging based on a simple regression hedge for soft and hard wheat. Results indicate two different simple regression hedging models perform as well, or better than, the K&S model. Note the difficulty of extending the K&S model when more than two deliverable grades exist; no such difficulty exists for the simple regression hedge model.
Viswanath (1993)	Problems with using a traditional regression method to calculate the hedge ratio estimate include the failure to adjust for convergence of spot and futures prices at maturity and a need to use conditional variance and covariance. Presents a basis corrected estimation method addressing both issues; uses the method to construct zero-value hedges that reduce the time variation in hedged portfolio returns. Comparison of financial results of hedge ratios based on the traditional and corrected method reveals the corrected method produces smaller portfolio return variances in many cases; however, corn hedges produce no improvement while soybean and wheat hedges yield only a weak improvement over the traditional method.
Shafer (1993)	Deals with the meaning and use of hedge ratios derived from a simple regression of end-of-hedge cash and futures prices and with price changes occurring during the hedge period. Notes: 1) hedge ratios in many previous studies reflect systematic basis behavior; 2) hedge ratios obtained from regressing price levels or price changes aids in forecasting the net price expected from a short or long hedge, but it does not forecast the direction of the price change, the closing basis, or the change in basis. Concludes that when reliable basis change models exist, merchants and other handlers of commodities should engage in discretionary hedging.

Pirrong, Kormendi, & Meguire (1994)	Investigate whether delivery point options affect the price of CBOT's corn and soybean futures contracts and how adding delivery points and adjusting for delivery differentials affects pricing and hedging performance. Results indicate both corn and soybean prices in eight regions (Chicago, Toledo, St. Louis, Central Illinois, Gulf of Mexico, Minneapolis, Central Iowa, and Kansas City) reflect the value of the existing option to deliver at various locations (Chicago or Toledo, Ohio) and changes in delivery specification for either grade or delivery location markedly affects the value of futures contracts as a risk management tool. The addition of a St. Louis delivery point leads to a diversification effect which improves the hedge results; the fact that St. Louis is a high correlation location enhances the hedge results even further.
Vukina, Li, & Holthausen (1996)	Derive optimal hedges in both the price and yield futures markets (the CBOT began trading crop yield insurance futures contracts in 1995; these contracts provide a hedge for crop yield risk). A comparison of hedging effectiveness (a price hedge only, a yield hedge only, both a price and yield hedge) shows a firm can reduce profit variance by hedging with both contracts. Results also indicate the effectiveness of a dual hedge relates to the volatility of the yield contract; the greater the underlying yield variance, the less effective the dual hedge is as compared to a price hedge only. Test results indicate the effectiveness of the yield hedge depends greatly on the price and yield bases.
Lence, Hayenga, & Patterson (1996)	A minimum-variance hedge ratio estimation model for storable commodities should include only information available at the time of placing a hedge; the information set should include the current basis. This type of model allows one to determine whether expected storage profitability affects the size of the hedge ratio. Results based on corn and soybean data support the hypothesis that actual hedge ratio estimates are influenced by the expected profitability of commodity storage. Additionally, results indicate desired hedge ratios decrease as expected profitability of storage increases.

Kenyon & Beckman (1997)	Find selective 3-year pricing of corn and soybeans could improve the overall price received for producers willing to accept more risk. The corn strategy yielding the highest prices involves pricing first year production with cash contracts and using futures contracts for the subsequent two years; price the commodities when December futures prices reach the top 5% of the historical futures price distribution. The soybean strategy requires selling three years of production when November futures prices exceed the top 10-15% of the historical futures price distribution. The producer must use put options with strike prices closest to current futures prices. These three-year strategies increase the average price of corn by \$0.47 per bushel and soybeans by \$1.00 per bushel above harvest cash prices; it yields \$0.37 per bushel for corn and \$0.83 per bushel for soybeans over routine annual pricing on April 15 each year.
Lien (2000)	When the production and futures hedging framework includes Knightian uncertainty, inertia exists in hedging behavior. This inertia typically exhibits itself not in the decision of “to hedge or not hedge” but whether to engage in a full hedge or not. Shows that a region for the current futures price exists within which a full hedge is the optimal hedge for forward contracting. Inertia in the regression hedge ratio becomes more widespread when the producer’s ambiguity increases or when the spot and/or futures price volatility increases.
Arias, Brorsen, & Harri (2000)	Propose an optimal hedge ratio model which includes yield risk, price variability, basis risk, taxes, and financial (bankruptcy) risk as independent variables. Indicate producers hedge when hedging costs less than the benefits that come from reducing tax liabilities, liquidity costs, or bankruptcy costs. Find that optimal hedge ratios are very fragile depending on the cost of hedging and that adding costs for a producer’s time or his dislike of futures could drive the hedge ratio to zero. State that “futures exchanges should favor progressive tax rates because they lead to more hedging.” However, when the producer has a net operating loss, the tax-loss carryback can eliminate the need for hedging just as income averaging may reduce the producer’s desire to hedge.

Lence & Hayenga (2001)	Evaluates whether hedge-to-arrive (HTA) contracts can, theoretically, lock-in high current prices for crops which will be harvested one or more years in the future using 107 years of data. Argues that standard price theory implies that the goal of locking-in higher prices with HTAs is not realistic and that if HTAs had not collapsed in 1996 due to other economic pressures, they would have in the future anyway. The regression results show that a “high proportion of an unusually high nearby futures price would be lost in a rollover . . .” thus providing support for the standard price theory.
Foster and Whiteman (2002)	Use Bayesian hedge ratios, a “naive” hedge ratio and a certainty equivalent hedge ratio to calculate hedge ratios for a hypothetical Iowa farmer who want to hedge his soybean harvest using Chicago futures contracts. They find that a Bayesian-based hedging program and the Naive procedure provide similar results for simple situations; however, when using more complex specifications, the Bayesian approach results in hedging a higher percentage (i.e., 89%) than the Naive approach for hedging horizons not exceeding six weeks. Indicate the Bayesian hedge ratio declines as the horizon increases.
Lien, et al. (2002)	In a study comparing the hedging performance of the constant-correlation GARCH hedge model to an ordinary least squares (OLS) model, they use out-of-sample optimal hedge ratio forecasts to evaluate each model’s performance. Their test results indicate that the simpler OLS model outperforms the more complex GARCH model in commodity, currency, and stock index futures markets.

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